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GROWTH AND FEEDING HABITS OF THE WHITING OR SILVER HAKE IN THE NEW YORK BIGHT[1]

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ABSTRACT

A total of 1,931 whiting were sampled from two fishing locations (Long Branch Pier and the "Mud Hole") in the New York bight from December 1957 through May 1958. All were measured for total length, and the weights of 455 were recorded. Sex was determined for the adults. Otoliths from 287 specimens, and stomach contents from 338, were preserved.

Calculated growth rates showed a highly significant difference between the sexes, but there was no evidence that growth of either sex varied with time or location. Neither was there evidence that length-weight relationships differed significantly.

Various amphipods and shrimps, together with glut herring and silversides, were the food items most frequently eaten. In the offshore area, whiting had taken smaller fish of their own kind to a considerable degree.

The whiting or silver hake (*Merluccius bilinearis*) occurs in the New York bight from November through May. While in this locality, these fish account for important commercial and sport fisheries. Indeed, the commercial catch of whiting for the Middle Atlantic states has exceeded 13 million pounds in a single year (Table 1).

Despite the importance of this resource, little is known about the life history of the species, e.g., its rate of growth, feeding habits, movements and migrations. Hickling (1927, 1933) conducted research in the British Isles on the seasonal distribution, feeding habits and rate of growth of the European hake (*Merluccius merluccius*). Bigelow and Schroeder (1953) made observations on the breeding and feeding habits of the whiting in the Gulf of Maine and suggested that this species probably is sexually dimorphic as far as growth is concerned. Aside from some morphometric studies by Ginsburg (1954) on the whitings along the American coasts, and a preliminary study by Clark (1954) on the escapement of whiting through trawl meshes, little other published information is available.

The research reported here was concerned with the growth and feeding habits of the whiting in the New York bight.

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[1] Derived from a Master's thesis submitted to the Graduate School, Rutgers University. The author extends particular thanks to Dr. James R. Westman for his guidance and critical examination of the thesis, and to Professor Kenneth Meinken for his invaluable advice on statistical procedures and the presentation of data. Many of the statistical computations were carried out by the Rutgers University Computation Center under the direction of Dr. Frederick G. Fender. Thanks are also due to the managements of Long Branch Pier and of the Belford and Point Pleasant Sea Food Cooperatives for allowing the writer to sample at these locations, and to Mr. and Mrs. Walter Frank and Mr. Louis Rooth for generously supplying whiting from their hook and line catches.

TABLE 1. COMMERCIAL CATCH OF WHITING IN WATERS OF THE MIDDLE ATLANTIC STATES* FOR VARIOUS YEARS FROM 1897 TO 1957§

Year	Catch in pounds
1897	13,000
1898	19,000
1904	737,000
1921	4,220,000
1926	7,521,000
1929	6,649,000
1930	4,113,000
1931	2,734,000
1932	2,705,000
1933	2,147,000
1935	5,629,000
1937	13,813,000
1938	10,184,000
1939	10,918,000
1940	8,388,000
1942	9,332,000
1943	13,505,000
1944	8,919,000
1945	11,611,000
1947	9,625,000
1948	1,655,000
1949	1,578,000
1950	1,837,000
1951	1,581,000
1953	4,223,000
1954	4,810,000
1955	8,197,000
1956	3,752,000
1957	6,661,000

* New York, New Jersey, Delaware.
§ Data from fishery statistics of U. S. Dept. Int.

PROCEDURE

There are certain major fishing areas for whiting within the New York bight, and sampling procedures were designed to include two of these. During winter and early spring, for instance, a commercial trawl fishery exists offshore in the areas between Scotland Lightship and the "Mud Hole" (Figure 1). During spring, whiting are taken inshore by pound nets along the coasts of Long Island and New Jersey. Sport fishing is done offshore in the vicinity of Scotland Lightship by "open" or "head" boats during the winter daylight hours and inshore at Long Branch Pier during the night.

Samples were taken from the trawl fishery in the Mud Hole area and from the sport fishery at Long Branch Pier.

During December 1957 and January 1958, a series of night collecting trips was made to Long Branch Pier at intervals of about one week. By preselecting individual fishermen, or groups of fishermen, on the pier in any one evening, a random portion of their total catch was sampled. It

is believed that, in this manner, a representative sample of fish was obtained.

The sampled fish were measured to the nearest half-centimeter (total length), and their gonads were examined to determine sex. Fish, i.e., immature, whose sex could not be determined were assigned a sex at random. Otoliths were removed and placed in vials containing 3 per cent tri-sodium phosphate and one drop of the bactericide "Slimodyn" (a colloidal silver salt). Stomachs were also removed, wrapped in cheesecloth, and placed in jars containing 10 per cent formalin. Whenever possible, unopened whiting were taken to the laboratory where they could be weighed.

Between February 1 and May 31, 1958, catches of whiting were sampled at two commercial fishery ports (Belford and Point Pleasant)

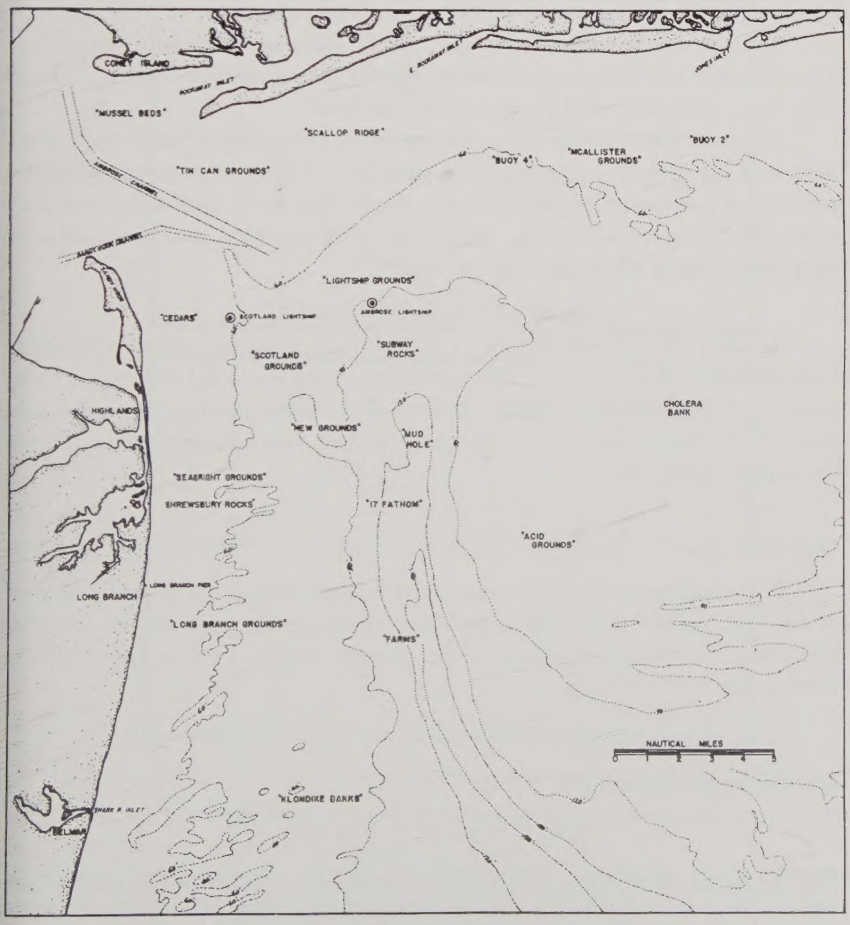

Figure 1. Map of New York bight showing location of fishery areas.

in northern New Jersey. At both of these locations, representative samples of whiting were purchased directly from trawlers returning from the Mud Hole area. These fish were taken to the laboratory and processed in the same manner as those sampled at Long Branch Pier. Otoliths were preserved from fish sampled offshore during February and March.

In order to determine the ages of the sampled fish from the otoliths, these "ear stones" were submersed at the laboratory in a blackened Petri dish containing tap water. Using a 3× hand magnifying glass, or occasionally a 6× binocular microscope, and a strong beam of focused light, the number of translucent rings in each otolith was counted and recorded along with the corresponding length of the fish from which it had been taken. This was a slight modification of the procedure outlined by Hickling (1933). These data were then subjected to regression analysis for sigmoid growth curves as described by Mills (1956, pp. 554–556).

Whiting were weighed by an Ohaus scale of 1100-gram capacity. The weight of each fish was recorded with its corresponding length. These data were also subjected to regression analysis.

Stomach contents were examined in the laboratory, and each food item was identified as accurately as possible. Using graduated cylinders containing tap water, the volumetric displacement of each item was also measured. From these data, frequency of occurrence and total volume were determined for each food present.

RESULTS AND DISCUSSION

A total of 772 male and 1,159 female whiting were measured. Length-frequencies of these fish were smoothed once by threes and are presented graphically in Figure 2; for ease of presentation, those fish less than 40 half-centimeters and more than 110 half-centimeters in length have been omitted.

GROWTH

Numerous investigations have shown that the growth of many species of fish follows the S-shaped population curve or sigmoid curve. In the absence of a function that might be more suitable, the Gompertz curve, having the natural form

$$y = ab^{c^x}$$

and the logarithmic form

$$\log y = \log a + (\log b)c^x,$$

was fitted to the data. Computations on the relationship of length to age, as indicative of the growth functions, yielded the following regression equations for male and female whiting:

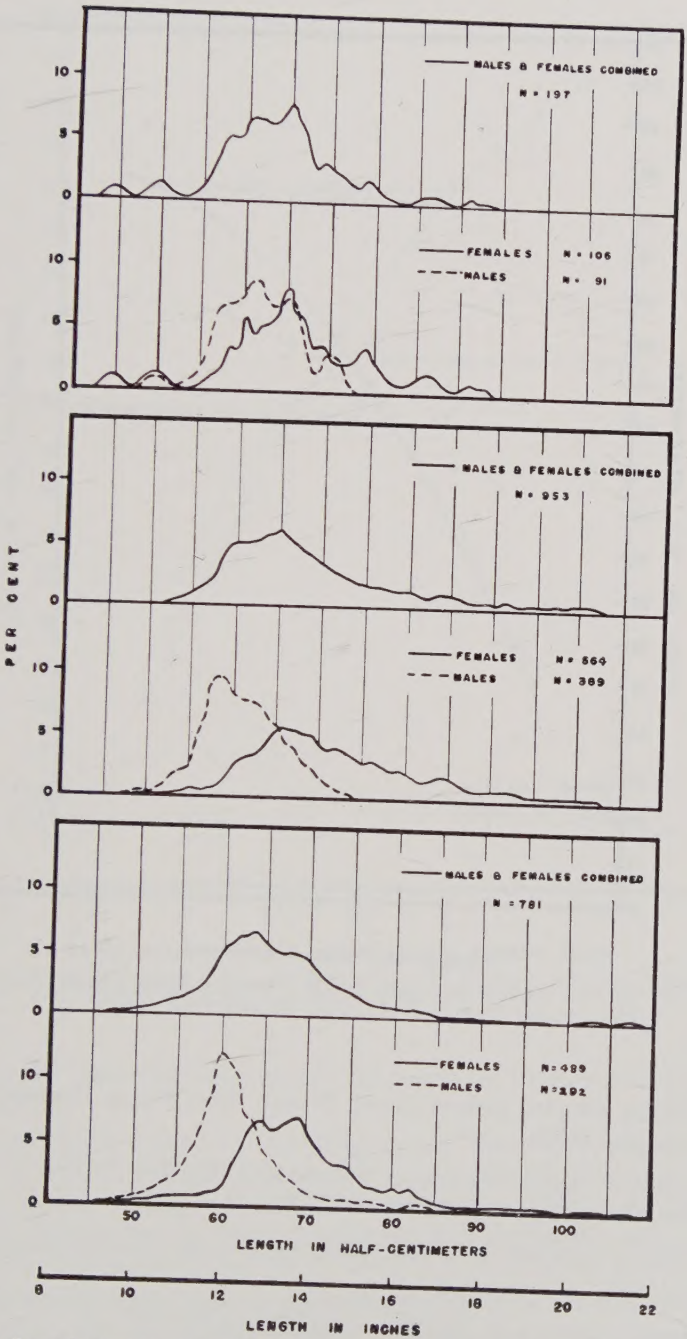

Figure 2. Length-frequency distributions for whiting sampled inshore at Long Branch Pier and offshore in the Mud Hole area: (top) inshore, December 1957 and January 1958; (middle) offshore, February and March 1958; (bottom) offshore, April and May 1958.

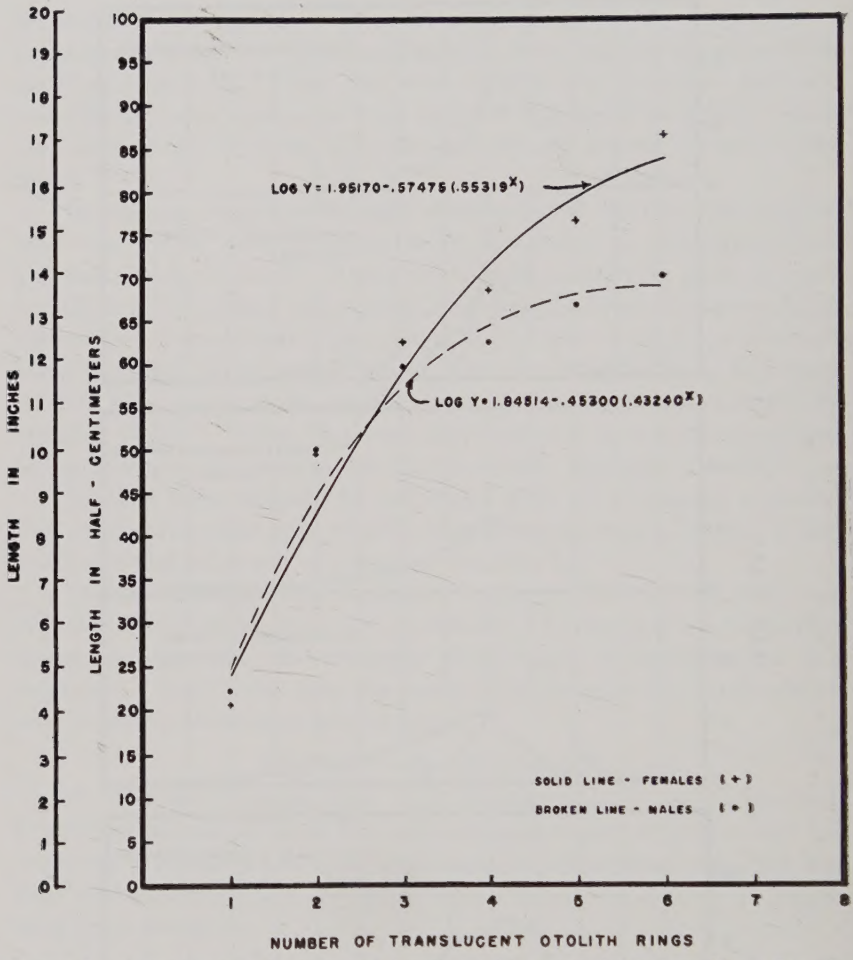
LOG Y = 1.95170-.57475 (.55319^X)
LOG Y = 1.84514-.45300 (.43240^X)
SOLID LINE - FEMALES (+)
BROKEN LINE - MALES (•)
LENGTH IN INCHES
LENGTH IN HALF - CENTIMETERS
NUMBER OF TRANSLUCENT OTOLITH RINGS

Figure 3. Growth rates of male and female whiting sampled inshore (Long Branch Pier) during December 1957 and January 1958.

for whiting sampled inshore (Long Branch Pier) during December 1957 and January 1958

$$\text{males:} \quad \log y = 1.84514 - 0.45300\ (0.43240^{x})$$
$$\text{females:} \quad \log y = 1.95170 - 0.57475\ (0.55319^{x});$$

for whiting sampled off shore (Mud Hole area) during February and March 1958

$$\text{males:} \quad \log y = 1.83310 - 0.45515\ (0.37277^{x})$$
$$\text{females:} \quad \log y = 2.04235 - 0.42024\ (0.64222^{x}).$$

Growth curves for the two sexes in each area are presented in Figures 3

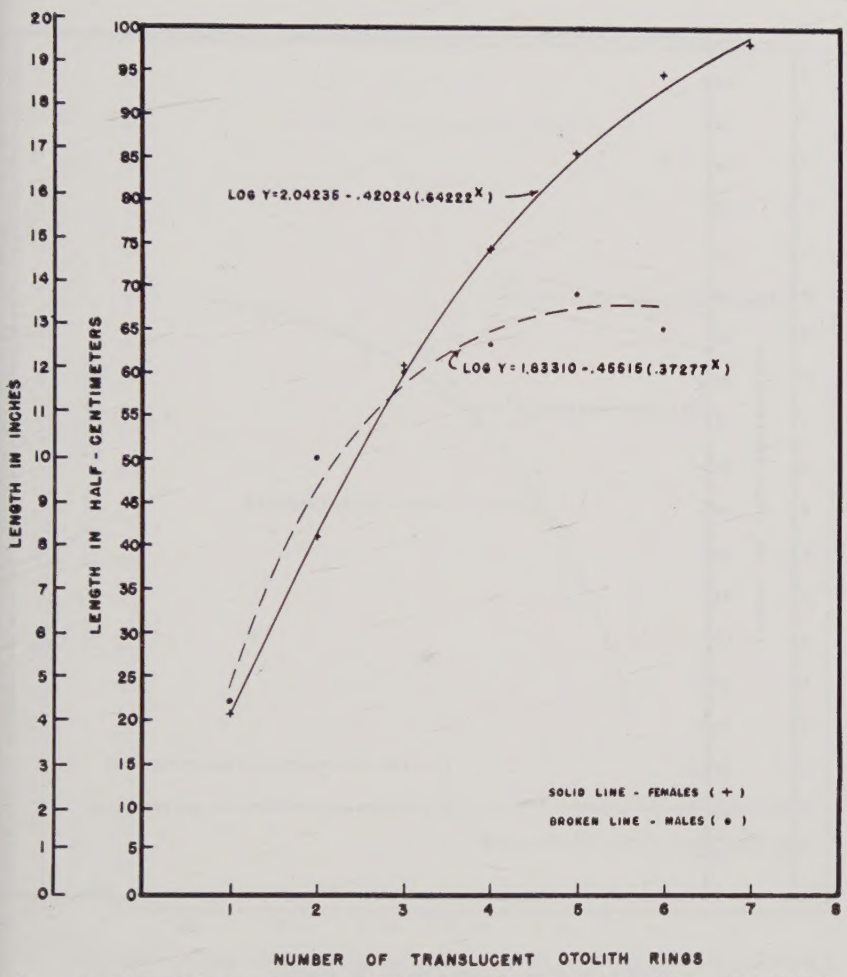
LOG Y=2.04235 - .42024(.64222^X)
LOG Y=1.83310 - .45515(.37277^X)
SOLID LINE - FEMALES (+)
BROKEN LINE - MALES (•)
LENGTH IN INCHES
LENGTH IN HALF-CENTIMETERS
NUMBER OF TRANSLUCENT OTOLITH RINGS

Figure 4. Growth rates of male and female whiting sampled offshore (Mud Hole area) during February and March 1958.

and 4, while curves for each sex in both areas are compared in Figures 5 and 6.

These curves suggest (1) that whiting are sexually dimorphic with respect to growth, and (2) that a difference in growth rates may exist between female whiting in the Mud Hole area and those in the inshore waters near Long Branch Pier. To test the null hypotheses, an analysis of variance was made (Table 2).

The results clearly indicate a significant difference between the rates of growth of male and female whiting. No significant difference, however, could be found between the growth rates of the females taken from the Mud Hole area and those taken at Long Branch Pier. The diver-

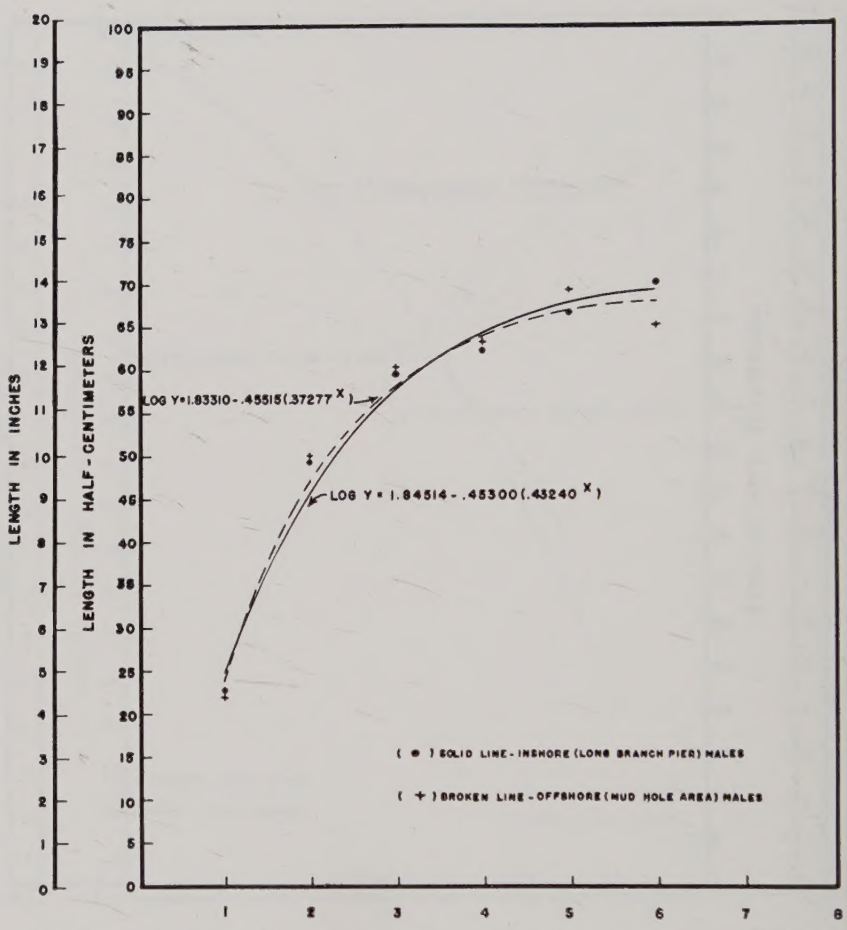
LENGTH IN INCHES
LENGTH IN HALF-CENTIMETERS
LOG Y=1.83310-.45515(.37277 X)
LOG Y = 1.84514 - .45300(.43240 X)
(●) SOLID LINE - INSHORE (LONG BRANCH PIER) MALES
(+) BROKEN LINE - OFFSHORE (MUD HOLE AREA) MALES

Figure 5. Growth rates of male whiting sampled inshore during December 1957 and January 1958 and offshore during February and March 1958.

gence of the curves shown in Figure 6 was apparently due to the presence of a few large fish from older age classes in the offshore samples.

LENGTH-WEIGHT RELATIONSHIPS

The length-weight relationship of many fish species can be expressed by the equation

$$X_1 = aX_2^b$$

or in the logarithmic form

$$\log_e X_1 = a + b \log_e X_2.$$

In the absence of a function that might be more suitable, this empirical equation was fitted to the data. Computations on the relationship of

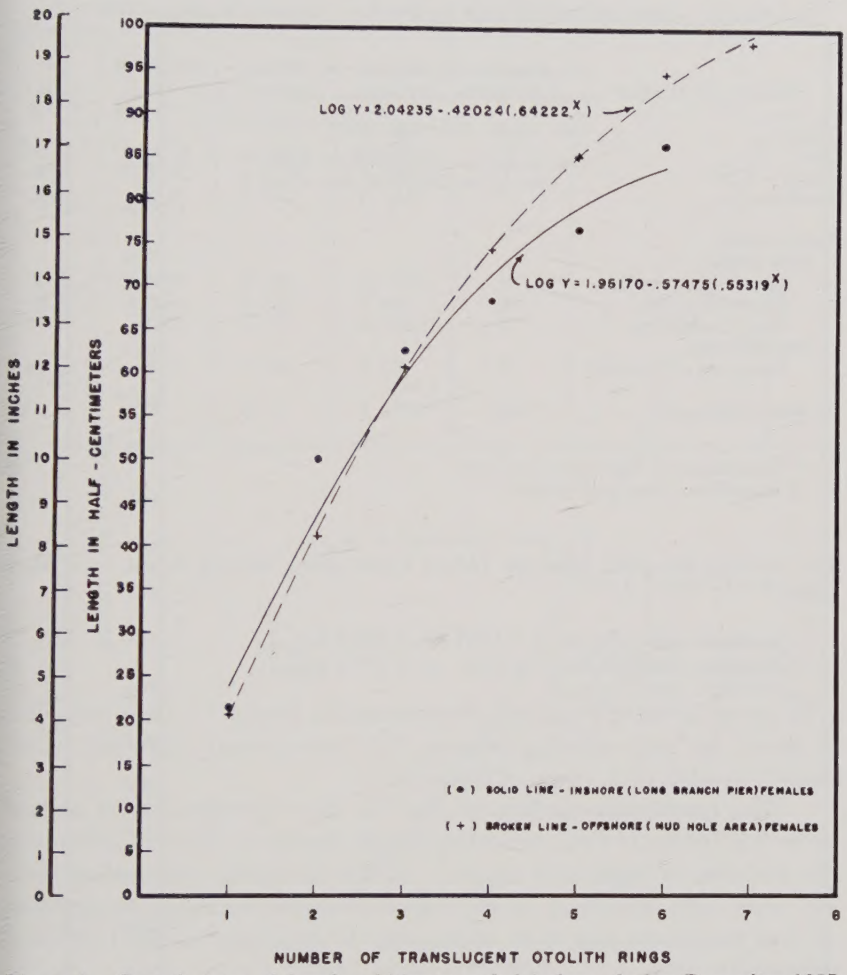
LOG Y = 2.04235 - .42024(.64222^X)
LOG Y = 1.95170 - .57475(.55319^X)
(•) SOLID LINE - INSHORE (LONG BRANCH PIER) FEMALES
(+) BROKEN LINE - OFFSHORE (MUD HOLE AREA) FEMALES
LENGTH IN INCHES
LENGTH IN HALF - CENTIMETERS
NUMBER OF TRANSLUCENT OTOLITH RINGS

Figure 6. Growth rates of female whiting sampled inshore during December 1957 and January 1958 and offshore during February and March 1958.

length to weight yielded the following regression equations for male and female whiting:

for whiting sampled inshore (Long Branch Pier) during December 1957 and January 1958

$$\text{males:} \quad \log_e X_1 = -7.6032 + 3.1275 \log_e X_2$$
$$\text{females:} \quad \log_e X_1 = -8.2799 + 3.2830 \log_e X_2;$$

for whiting sampled offshore (Mud Hole area) during February and March 1958

$$\text{males:} \quad \log_e X_1 = -7.4004 + 3.0759 \log_e X_2$$
$$\text{females:} \quad \log_e X_1 = -7.6200 + 3.1276 \log_e X_2;$$

TABLE 2. ANALYSIS OF VARIANCE OF DATA ON GROWTH RATES OF WHITING

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value of F	F (.01)
Total	95	7597.2	.....	....	....
Age	2	2779.0	1389.5	41.35**	4.88
Sex	1	956.4	956.4	28.46**	6.96
Situation§	1	110.5	110.5	3.29	6.96
Interactions					
First order					
Age *vs.* sex	2	677.6	338.8	10.08**	4.88
Situation *vs.* sex	1	19.3	19.3	0.57	6.96
Age *vs.* situation	2	189.4	94.7	2.82	4.88
Second order					
Age *vs.* sex *vs.* situation	2	43.9	22.0	0.65	4.88
Within subclasses	84	2821.1	33.6	....	....

** Significant at the 1 per cent level.
§ Represents time and location.

for whiting sampled offshore (Mud Hole area) during April and May 1958

$$\text{males:} \quad \log_e X_1 = -7.4491 + 3.0855 \log_e X_2$$
$$\text{females:} \quad \log_e X_1 = -6.9329 + 2.9772 \log_e X_2.$$

The curves for these equations are presented in Figure 7. Only one curve is shown for male whiting because the three actually involved would largely overlap on a graph of this scale.

The correlation coefficients (r_{12}) for the regression curves ranged from 0.97749 to 0.99355, indicating a high degree of relationship between the variables of length and weight. To test the significance of these data, "t" tests were performed on the regression coefficients of each equation. It was discovered that each relationship is significant at the 1 per cent probability level.

Although a formal statistical procedure could have been applied to test for the significance of differences between the lines of regression, this was not considered necessary since the difference between the regression coefficients in all cases was less than one standard error of any regression coefficient.

FEEDING HABITS

The stomach contents of 137 whiting sampled at Long Branch Pier and 201 from the Mud Hole area were examined. The results are given in Tables 3 and 4.

Whiting from the inshore fishery at Long Branch Pier appear to feed quite extensively on amphipods and the sand shrimp (*Crago septemspinosus*) as indicated by their frequency of occurrence. Among fish species, glut

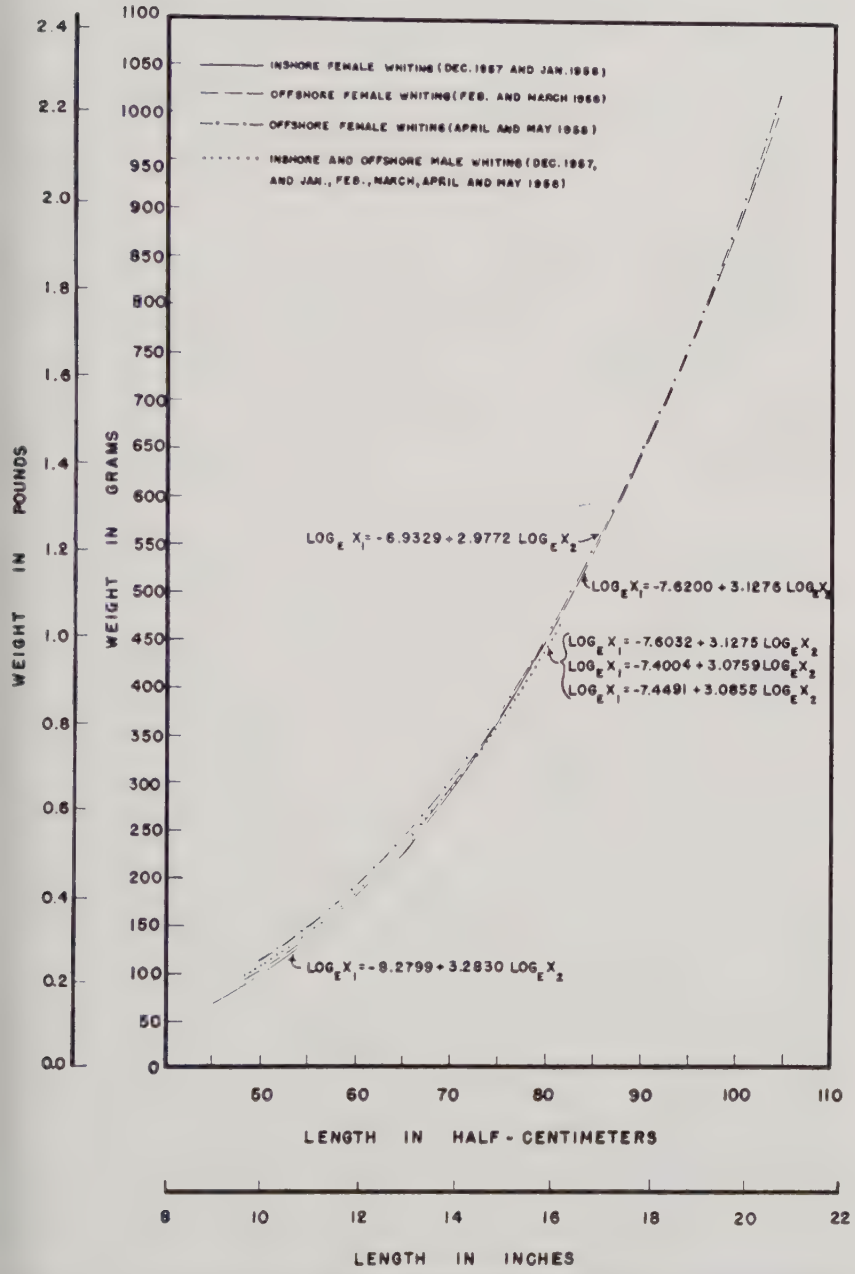
INSHORE FEMALE WHITING (DEC. 1957 AND JAN. 1958)
OFFSHORE FEMALE WHITING (FEB. AND MARCH 1958)
OFFSHORE FEMALE WHITING (APRIL AND MAY 1958)
INSHORE AND OFFSHORE MALE WHITING (DEC. 1957, AND JAN., FEB., MARCH, APRIL AND MAY 1958)
LOG$_E$ X$_1$ = -6.9329 + 2.9772 LOG$_E$ X$_2$
LOG$_E$ X$_1$ = -7.6200 + 3.1276 LOG$_E$ X$_2$
LOG$_E$ X$_1$ = -7.6032 + 3.1275 LOG$_E$ X$_2$
LOG$_E$ X$_1$ = -7.4004 + 3.0759 LOG$_E$ X$_2$
LOG$_E$ X$_1$ = -7.4491 + 3.0855 LOG$_E$ X$_2$
LOG$_E$ X$_1$ = -8.2799 + 3.2830 LOG$_E$ X$_2$
WEIGHT IN POUNDS
WEIGHT IN GRAMS
LENGTH IN HALF-CENTIMETERS
LENGTH IN INCHES

Figure 7. Length-weight relationships of male and female whiting sampled inshore (Long Branch Pier) and offshore (Mud Hole area) between December 1957 and May 1958.

TABLE 3. STOMACH CONTENTS OF 137 WHITING TAKEN AT LONG BRANCH PIER DURING DECEMBER 1957 AND JANUARY 1958*

Food item	Frequency of occurrence	Relative frequency (per cent)	Volume (milliliters)	Relative volume (per cent)
Invertebrates	60	43.80	34.98	9.45
Arthropoda				
Crustacea				
Mysidacea	12	8.76	1.05	0.28
Cumacea	2	1.46	0.07	0.02
Isopoda	5	3.65	0.18	0.05
Amphipoda	40	29.20	9.04	2.44
Decapoda	..	....	....	....
Crago septemspinosus	29	21.17	24.24	6.55
Palaemonetes vulgaris	1	0.73	0.30	0.08
Annelida				
Chaetopoda				
Polychaeta	1	0.73	0.10	0.03
Vertebrates	63	45.99	335.14	90.55
Pisces				
Pomolobus aestivalis	20	14.60	98.40	26.59
Menidia menidia	12	8.76	86.50	23.37
Brevoortia tyrannus	2	1.46	15.50	4.19
Ammodytes americanus	1	0.73	0.90	0.24
Anchoviella mitchilli	1	0.73	0.35	0.09
Merluccius bilinearis	1	0.73	84.00	22.70
Paralichthys dentatus	1	0.73	0.04	0.01
Fish remains	33	24.09	49.45	13.36

* 43 specimens (31.39 per cent) were empty.

herring (*Pomolobus aestivalis*) and silversides (*Menidia menidia*) occurred most frequently.

It is of considerable interest to note that a small, post-larval fluke or summer flounder (*Paralichthys dentatus*) was found in the stomach of a male whiting taken at Long Branch Pier on the night of December 30, 1957. It was previously believed that fluke of this size did not inhabit these inshore waters at this time of year.

It would also appear that whiting occurring in the Mud Hole area play an important part in their own ecology, e.g., whiting were found in 48 of the stomachs examined from this location, and they displaced an aggregate volume of over 1,000 milliliters. Indeed, one female whiting, 113 half-centimeters in length, was found to have consumed another whiting 53 half-centimeters long, a fish nearly half its own size. Such feeding habits as these could conceivably influence the size of the whiting population of the New York bight in any given year, especially if there were a corresponding shortage of other food organisms.

Of particular interest was the occurrence of shad (*Alosa sapidissima*), which appeared to be "zero" or yearling fish, in seven of the whiting stomachs collected from the Mud Hole area between March 14 and

TABLE 4. STOMACH CONTENTS OF 201 WHITING TAKEN IN MUD HOLE AREA DURING FEBRUARY, MARCH, APRIL AND MAY 1958*

Food item	Frequency of occurrence	Relative frequency (per cent)	Volume (milliliters)	Relative volume (per cent)
Invertebrates	97	48.26	825.40	27.80
Arthropoda				
Crustacea				
Mysidacea	20	9.95	32.49	1.09
Cumacea	6	2.99	2.85	0.10
Isopoda	1	0.50	0.03	0.00
Amphipoda	3	1.49	0.23	0.01
Decapoda	..	....	....	....
Crago septemspinosus	77	38.31	491.25	16.55
Mollusca				
Cephalopoda				
Decapoda				
Loligo pealii	8	3.98	298.30	10.05
Annelida				
Chaetopoda				
Polychaeta	1	0.50	0.25	0.01
Vertebrates	122	60.70	2143.20	72.20
Pisces				
Merluccius bilinearis	48	23.88	1000.70	33.71
Pomolobus aestivalis	13	6.47	248.00	8.35
Phycis chuss	13	6.47	264.00	8.89
Anchoviella mitchilli	9	4.48	67.00	2.26
Alosa sapidissima	7	3.48	126.40	4.26
Poronotus tricanthus	6	2.99	106.00	3.57
Ammodytes americanus	5	2.49	34.00	1.15
Menidia menidia	1	0.50	2.00	0.07
Stenotomus chrysops	1	0.50	34.00	1.15
Tautoga onitis	1	0.50	97.00	3.27
Fish remains	39	19.40	164.10	5.53

* 39 specimens (19.40 per cent) were empty.

May 2, 1958. The whereabouts of these fish during the late winter and spring months has never been definitely established.

Whiting sampled from the trawl fishery were also found to have been feeding rather extensively upon the sand shrimp (*C. septemspinosus*). This species was present in 77 stomachs examined from the Mud Hole area. The opossum shrimp (*Mysidacea*) occurred in 22 stomachs taken from this location. Many small whiting that were found in the stomachs were, in turn, opened and their stomach contents examined: all contained opossum shrimp in rather large numbers.

PARASITISM

Of passing interest is the fact that the viscera of every whiting examined during the study was parasitized to some degree by plerocercoid

(larval) tapeworms. These were identified by Dr. Ross F. Nigrelli of the New York Aquarium as "belonging to the group Tetrarhyncha or Trypanorhyncha and are similar to the species *Lacistorhynchus tenuis*, the larval stage of which is widely distributed in the peritoneal cavity of many species of teleosts of the North Atlantic". The effect of these parasites on the whiting population of the New York bight is unknown.

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PATHOLOGY, PARASITOLOGY AND HEMATOLOGY OF THE BLACK BEAR IN NEW YORK[1]

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Hugh C. Black[3] — Research Assistant, Department of Conservation, Cornell University

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ABSTRACT

Results are reported from autopsy of 65 wild bears and 17 captive bears obtained from zoos. An additional 241 live-trapped wild bears were examined for external parasites and gross lesions. Ectoparasites were very scarce. Of 306 wild bears, lice (*Trichodectes*) were found on 23 and ticks (*Ixodes*) on only two. Roundworms (*Toxascaris*) were fairly common, occurring in 20 of 65 specimens. A new species of lungworm of the genus *Crenosoma* was found. Microfilariae (*Dirofilaria ursi*) were present in blood smears from 47 of 101 examined. Pieces of diaphragm from 49 bears were examined for trichinae; three were positive. Gross lesions, mostly from healed gunshot wounds, are described. Hematological data are presented for eight individuals.

An investigation of the black bear (*Ursus americanus*) in New York from 1956 to 1958 made 323 animals available for study, of which 82 were autopsied. All but 17 were wild bears trapped within the State. Published information on parasitism in the black bear is scarce, and no previous reports have treated the pathology of this species. The objective of this research was to determine the incidence and severity of parasitism and pathology in the specimens available for examination. Special attention was given to the possibility that bears in this State may serve as hosts to parasites of public health and veterinary importance. For example, since Horstman (1949) reported the presence of trichinae in black bears in Colorado the present study included a search for this parasite in 49 out of the 65 wild bears autopsied. Data on hematology were obtained from eight bears.

A review of the literature on parasitism in bears by Horstman (*op. cit.*) states that four parasites of public health importance have been reported, namely, trichinae (*Trichinella spiralis*), the broad tapeworm (*Diphyllobothrium latum*), the hydatid worm (*Echinococcus granulosus*) and the wood tick (*Dermacentor andersoni*). Five parasites of veterinary importance were reported, namely, the common stomach worm (*Haemonchus*

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-89-R. The project leader was C. W. Severinghaus. The study was part of an investigation of the black bear in New York carried on under contract with the Department of Conservation of Cornell University. Appreciation is expressed to Dr. Charles G. Rickard of the College of Veterinary Medicine at Cornell for providing laboratory facilities and services. Thanks are due also to Drs. J. H. Whitlock, J. S. Mackiewicz and B. V. Travis of Cornell for identifying parasites.

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contortus), the salmon-poisoning fluke (*Troglotrema salmonicola*)[4], the dog hookworm (*Ancylostoma caninum*), the hydatid worm and the wood tick.

Examination by Horstman of five bears killed in southwestern Colorado during the summer of 1948 showed one to be carrying a wood tick and two to be infected with three species of tapeworms; two of the latter were previously undescribed. One adult male had five small tapeworms in the duodenum; of these, two were immature forms of *Taenia pisiformis* and three were a new species, *Mesocestoides krulli*. Thirty-six fragments of a diminutive cestode were found in the small intestine of the other bear, also an adult male. This previously undescribed species was named *Anacanthotaenia olseni*.

The ascarid worm (*Toxascaris multipapillata*) has been reported in several bears, including the black bear (Horstman, *op. cit.*).

Anderson (1951, 1952) reported on a large collection of filariid worms found in subcutaneous tissues of all the black bears examined from Algonquin Park, Ontario, which he referred to as *Dirofilaria ursi* Yamaguti, 1941. The males and microfilariae of this species were described for the first time and the females were described more fully. *D. ursi* was compared with all other members of the genus and found to be distinct.

Herman (1944) listed the bear as host for the eyeworm (*Thelazia californiensis*).

Seven species of ectoparasites, including ticks, lice and fleas, have been reported from bears. Henshaw and Birdseye (1911) found adult wood ticks (*Dermacentor andersoni*) on bears from the Bitter Root Valley in Montana. The species of the host bears were not stated. Cooley (1938) listed the grizzly bear (*Ursus horribilis*) as a host for *D. andersoni*. Stiles and Baker (*op. cit.*) recorded six other ectoparasites from bears, including three species of the tick genus *Rhipicephalus*, and two genera of fleas (*Arctopsylla* and *Trichopsylla*). Hopkins (1954) described a new subspecies of Mallophaga (*Trichodectes pinguis euarctidos*) from a black bear from British Columbia; he also examined 84 male and 89 female specimens of this louse from a single black bear collected in Algonquin Park, Ontario.

The broad tapeworm has been found in bears in Yellowstone National Park according to Scott and Honess (1934). Scott (1934) also found *Diphyllobothrium cordatum* in bears from the same locality. These authors did not state which species of bears were examined. Skinner (1935) reported *D. latum* from black bears in Yellowstone Park.

PROCEDURES

Procedures varied according to whether a bear was dead (or to be killed for autopsy) or not. Dead specimens were given complete autop-

[4] The salmon-poisoning fluke, the only trematode reported from bears, was included on the basis of an experimental infection recorded by Stiles and Baker (1935).

sies, although the techniques differed somewhat depending on whether the work was done in the field or in the laboratory. Live bears, either captive or wild-trapped, that were not to be sacrificed were handled with the aid of drugs, e.g., ether, pentobarbital sodium or succinylcholine chloride (Black *et al.*, 1959), and were examined primarily for ectoparasites.

The methods used in making autopsies, in the field and in the laboratory, were those employed at the College of Veterinary Medicine at Cornell (King, 1959). In each case, the bear was laid on its left side with its head to the examiner's right. General condition and superficial lesions were noted, and external parasites were collected. The body cavity was opened by making a skin incision at the axilla and extending it forward to the symphysis of the mandible and back to the perineum on the right side. The two right limbs were then reflected along with the skin, exposing the entire right subcutaneous portion of the carcass. Lymph nodes, and mammary glands or penis and testes, were examined at this time. The abdominal cavity was opened with an incision along the costal arch and down the midventral line. After cutting the diaphragm, the right half of the rib cage was removed, exposing the thoracic viscera. The various organs were examined *in situ* and then removed by organ systems and examined individually. All endocrine glands were examined when removed and preserved for histologic studies. Portions of the diaphragm and any tissues suggestive of having lesions were removed and fixed in 10 per cent formalin for subsequent microscopic examination. A few samples of diaphragm tissue were examined for the presence of trichinae, using the method described by Hill (1951). This involves grinding the muscle in a blender, and recovering encapsulated larvae in a 200-mesh screen.

Blood samples for hematological studies and examination for microfilariae were taken from bears autopsied at Cornell. Blood smears were made of all bears handled in the field.

Hematological examination was made of eight bears, comprising four adult wild males, one adult wild female, two captive males (one adult and one sub-adult) and one captive cub. The blood was obtained from the jugular vein or the brachial artery, at the time of euthanasia, with a heparinized syringe. The leucocycte, erythrocyte, and differential counts and the hemoglobin and hematocrit values were obtained by standard techniques (Coffin, 1953). The blood urea nitrogen values were obtained by the techniques of Caraway (1955). From one specimen, a mature male, blood calcium values were obtained by the Clark and Callip method, magnesium by the Orange and Rheim method, and phosphorus by photoelectric colorimetry.

Intensive parasitological examination was made of the lungs, of mesenteric tissues in the region of the pharynx, and of the gastro-intestinal

tract. The larynx, trachea, bronchi and small bronchioles were opened to check for the presence of lungworms. The connective tissues in the region of the larynx and trachea were examined especially for filarial worms in most bears autopsied, both wild and captive. The stomach was opened and its contents were removed and examined grossly. Some stomach samples were examined with a binocular microscope, but no parasites were recovered; the technique was considered impractical and discontinued. The entire intestine was opened and its contents were examined for parasites. Screening techniques for collecting parasites were not used. All tissues were checked for pathological conditions.

Field autopsies were performed in the open or in abandoned lumber-camp buildings. Instruments and accessory equipment were stored in specially fitted boxes carried in pick-up trucks, as operations were not conducted from a central station. The principal items included boning knives, a dissecting kit, bone saw (used principally to facilitate removal of the pituitary gland), galvanized buckets, specimen jars and fixatives. Ten per cent formalin was used for most pathological specimens. Parasites were preserved in 70 per cent alcohol.

FINDINGS

Autopsy data were recorded for 65 wild bears and 17 from zoos. An additional 241 wild bears were examined for external parasites and gross pathological conditions in conjunction with live-trapping operations.

Pathology and Parasitology

Findings may be conveniently reported in four groups (Table 1). The largest group was made up of 241 individuals trapped, marked and released following gross examination; the second group consisted of 55 wild bears autopsied in the field; the third included 10 wild bears transported alive to Cornell for autopsy at the Veterinary College; and the fourth group comprised 17 captive (zoo) bears which were also transported alive to the Veterinary College for autopsy.

Group I The 241 individual bears in this group provided 315 examination records because some were handled on several different occasions. With the exception of five taken in Allegany State Park, these animals were live trapped in the Adirondacks, mainly in Hamilton, Franklin, Essex and St. Lawrence Counties. Males outnumbered females by about three to one. Ages ranged from cubs to adults estimated to be more than nine years old.

Twenty-one bears from this group had from a few to many lice of the species *Trichodectes pinguis euarctidos* (Hopkins, 1954) present on the ventral thoracic and ventral abdominal parts of the body. This species has not been reported previously from New York and was not listed by Scanlon (1955). Each of two bears carried one tick of the genus *Ixodes;*

TABLE 1. INCIDENCE OF PARASITISM AND LESIONS IN 323 BLACK BEARS

Item	Wild bears			Zoo bears
	Group I	Group II	Group III	Group IV
Number of individuals	241	55	10	17
External parasites				
Lice	21	..	..	..
Ticks	2	2	..	..
Internal parasites				
Microfilariae	34 (of 36)	3	10	.
Lungworms	..	3	3	..
Roundworms	..	17	3	5
Trichinae	..	3 (of 45)	0 (of 4)	..
Gross lesions				
Tumors or warts	4	..	..	..
Abscesses or pustules	10	2	..	..
Hernia	1	..	..	..
Missing toes	3	2	1	..
Missing feet	..	1	..	..
Healed fractures	5	5	1	..
Other	2 had wire collar or snare	1 had expanded bullet on frontal bone	..	1 had healed pelvic lesions

one in the right axillary region and one on the neck. Identification of the ticks to species was not possible because mouth parts are missing on our specimens; however, Professor B. V. Travis believes that they are probably *Ixodes cookei*.

Two bears had wire collars around the neck, which were tight and partly covered by skin and scar tissue. These devices probably became attached by encounter with illegal snares. Several bears had abscess-like lesions. One had an abscess behind the base of the right eye. Another had a large abscess in one testis which extended into the epididymus, and one No. 4 shot pellet was found in the connective tissue of this testicle. An arrowhead was recovered from an open wound in the right shoulder of a bear; pus was draining from the wound. On the medial side of the left stifle of another, there was a half-inch draining abscess. Another bear had an ankylosed right elbow joint which was enlarged and had a draining abscess. Two bears each had a suspected tumor about 1 inch in diameter; one was located on the left eyelid and one on the right side of the scrotum. Both were removed and preserved in 10 per cent formalin. Examination showed evidence of granulation tissue but no neoplasia. Wart-like lesions were found on two bears; one had lesions on the side of the scrotum and on the side of the mouth, and the other had a wart on the left shoulder. These were not examined

microscopically. One bear had what appeared to be an abdominal hernia, to the left of the penis and approximately 3 inches in diameter. However, when this bear was retrapped two years later, this condition was not noted. Each of three bears had one or two toes missing from a forefoot, and two bears had twisted forelimbs apparently resulting from healed fractures of the distal ends of the limbs. Three bears had bent tails, indicating fractures. Five animals had small scattered pustules up to about 5 millimeters in diameter, from which pus could be expressed. The pustules were concentrated mainly in the less hairy areas and around the neck. It was thought that these might have been infected fly bites. One bear had a marked loss of hair on the top of the head and on the sides of the neck.

Microfilariae were found in blood samples from 34 of 36 wild bears. The probable major source of these larvae is the filariid worm (*Dirofilaria ursi*) which was first reported in the black bear by Anderson (1951, 1952). This species was found in peritracheal tissues of the neck in 3 of 55 bears autopsied in the field. However, one may question that *D. ursi* was the source of all the microfilariae found in the bears because only a few adult filariids were discovered. There are other species of filariids occurring in carnivores, some of which are relatively small in the adult stage and may have been overlooked.

Group II The 55 bears in this group were live trapped and were killed purposely by overdoses of anesthetic. One was shot. Most of them were adult females taken in Hamilton, Franklin, Essex and St. Lawrence Counties. Estimated ages ranged from 1½ years to 8½ years. Two were cubs, one a female and one a male. Only five adult males were included.

It is interesting to note that neither ectoparasites nor endoparasites were recovered from the two cubs. Among the 53 adults, three had lungworms in the larger air passages; one individual contained 25 worms. This lungworm was identified by Dr. J. H. Whitlock as a new species of the genus *Crenosoma*, and will be described by him. Two or more ascarids (*Toxascaris multipapillata*) were recovered from the intestines of 17 bears; one contained a total of 39. Adult filariids (*Dirofilaria ursi*) were found in three of this group and were located in the soft tissues in the ventral part of the neck, particularly in the region of the thyroid glands along both sides of the trachea. Pieces of diaphragm of 45 of these bears were preserved in 10 per cent formalin, subsequently sectioned at 6 microns and examined microscopically. Three of the 45 samples were positive for *Trichinella spiralis*, and it is probable that our field method may have failed to detect trichinae in other bears. One of the infected specimens had 21 encysted larvae in a single microscopic section of muscle tissue (Figure 1).

The probable source of trichinae infection for wild bears in New York

Figure 1. Encysted larvae of *Trichinella spiralis* in muscle from the diaphragm of a black bear. (×400)

is uncooked garbage which may include scraps of infected pork. Many bears often feed at the numerous garbage dumps scattered throughout the bear range. Positive identification of trichinae in New York bears should serve as a warning that bear meat should be cooked thoroughly or frozen before cooking. Freezing will destroy trichinae (Ransom, 1916).

Gunshot wounds, identified mainly by lead remaining in tissues, and wounds caused by natural accidents were found in nine of this group. One of the bears had an expanded lead bullet in the depression of the right frontal bone just medial to the zygomatic process of the malar bone. Surrounding this bone was a slight elevation of osseous tissue. This was probably a spent bullet that hit the skull without sufficient force to penetrate. The left humerus of this bear had been fractured and had healed abnormally causing an approximately 2-inch shortening of the bone (Figure 2). Another bear had its tail broken 1½ inches from the tip, and its right hind foot was missing. A firm, tough portion of skin had healed over these stumps. A ¾-inch open wound was present in the anal area of one bear, apparently an infected puncture wound. Another bear had only one toe on its right front foot and the anterior portion of the main pad was also missing.

Figure 2. Skull showing lodged bullet and abnormally healed humerus of black bear that apparently had been wounded by gunfire.

One other bear had a bony ankylosis of the right stifle. This was characterized by abnormal bone growths around the joint. Radiographs showed lead in the bone immediately behind the joint. The distal end of the femur, proximal ends of both the tibia and fibula, and the patella were incorporated into the large, abnormal bony mass. In over-all width the joint was only slightly wider than normal, but this exostosis resulted in an immovable joint.

The pelvis and head of the femur of an adult female were abnormal. The sacrum and left ossa coxarum were normal, but the shaft of the right ileum presented a very rough, irregular shape, with several large, smooth-walled perforations. The acetabulum was absent, there being only a depression in the area where it should have been. The right pubis was roughened by exostoses, as was the right ischium. The entire pelvic symphysis was narrowed so that the ventral floor of the pelvic canal was in the form of a narrow "V" (Figure 3). The head of the femur was very rough and irregular. Radiographs revealed small bits of lead.

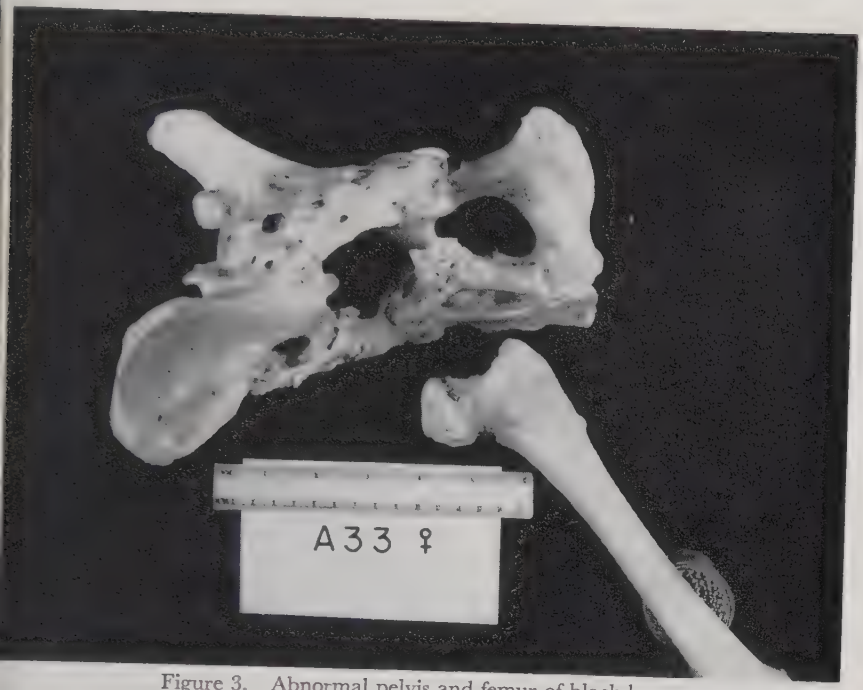

Figure 3. Abnormal pelvis and femur of black bear.

Figure 4. Skull of black bear apparently wounded by gunfire.

A healed wound, probably from gunshot, affected the muzzle of a bear in the following manner. The right premaxilla and part of the maxilla were absent, along with the teeth supported by these bones, so that only the molars and posterior premolar remained in the right upper jaw (Figure 4).

The left scapula of another bear showed the effects of a healed gunshot wound. The spine of the scapula was absent in its proximal fourth, and the anterior angle presented a roughened surface and an irregular edge (Figure 5). A radiograph of this lesion showed several small pieces of lead in the bone.

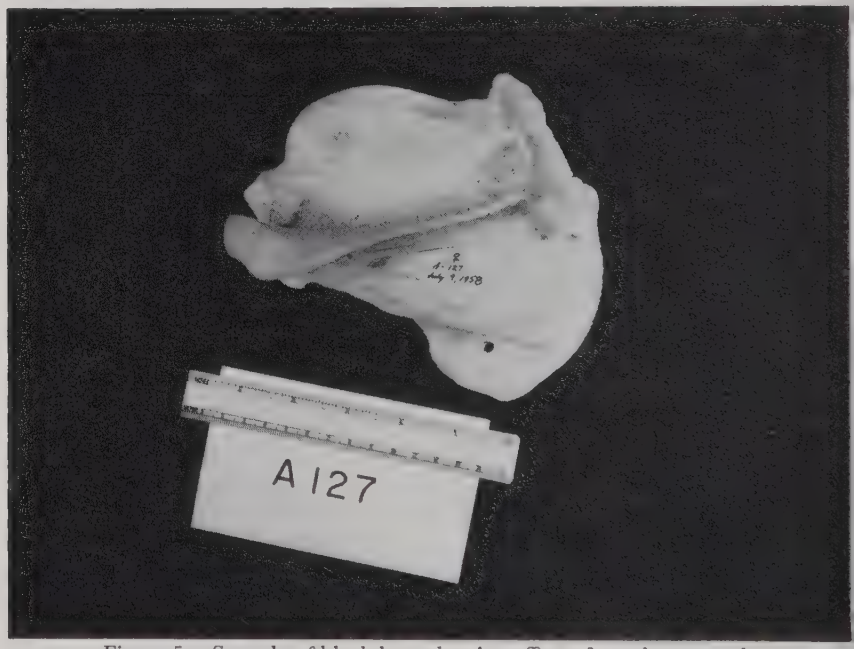

Figure 5. Scapula of black bear showing effect of gunshot wound.

Microscopic examination of several tissues with suspected lesions, taken from this group of bears, revealed the following pathological conditions. One bear had a marked but slight amount of bronchiectasis. The reason for this was not determined. Another showed a marked emphysema of the lung that may have been an effect of ether. A third showed numerous micro-abscesses in both the diaphragm and the liver. It is probable that this bear had a bacterial septicemia. One bear had a typical verminous pneumonia with lungworms present in the tissues. This same animal had scattered degenerative changes (Zenker's degeneration) in its heart. Two bears of this group had several lice present, scattered mainly on the ventral thoracic and abdominal areas.

GROUP III This group of 10 adult bears, five male and five female, were live trapped in the Adirondacks. Microfilariae were found in the blood of all specimens. Three had lungworms in the bronchi of the left apical lobe of the lung only. Up to 12 lungworms were removed from one bear. One individual had lungworm larvae in its feces. One had several old rib fractures with pleural and lung adhesions. Three females each had two roundworms (*Toxascaris multipapillata*) in the intestinal tract. Diaphragm tissues of four were negative for trichinae; the other six in this group were not examined for this parasite. Three bears were examined for protozoan parasites of the mouth and mucosa of the large and small intestines. None were found.

Because no evidence of abnormal behavior was noted, the brains of only two bears of this group were microscopically examined for evidence of nerve tissue lesions. Findings were negative.

GROUP IV Nine males and eight females comprised this group of 17 known-age bears obtained from zoos in New York State. Their ages ranged from 1½ to 7½ years. It is interesting to note that neither microfilariae in the blood nor adult filariids were found in any of these animals. No external parasites were found, but five bears had several roundworms (*Toxascaris multipapillata*) in the small intestine; 17 were recovered from one individual. One female had several thin-walled cysts in both kidneys. These were considered to be congenital defects.

The adrenal glands of three of this group were smaller than normal. Several investigators have noted decreases in the size of adrenals of wild mammals held in captivity. Richter and Uhlenhuth (1954) have reported markedly smaller adrenals in domesticated Norway rats compared with wild specimens. They assume that, in domestication of the rat, the gonads have assumed control of some functions that, in the wild state, are predominantly controlled by the adrenals. Christian and Ratcliffe (1952) described 14 examples of fatal "shock disease", in all of which a reduction in adrenal size was noted. These investigators suggested that the adrenal cortex had undergone partial atrophy through inactivity.

HEMATOLOGY

Hematological data for five wild and three captive bears autopsied in the laboratory are presented in Table 2; they may be compared with figures given by Svihla *et al.* (1955) and Youatt and Erickson (1958). In the single specimen examined for blood calcium, magnesium and phosphorus, the respective values were 11.25, 7.35, and 2.35 milligrams per 100 milliliters.

URINALYSIS

A partial analysis was made of urine from four adult bears (three wild and one captive) listed in Table 2. Urinalysis was not carried out

TABLE 2. HEMATOLOGICAL DATA FOR EIGHT BLACK BEARS

Date	Sex	Age (years)	Weight (pounds)	Blood urea nitrogen (milligrams per 100 milliliters)	Segmented leucocytes *	Lymphocytes *	Hemoglobin (grams per liter)	Blood cells (number per milliliter)	
								Red	White
Wild bears									
1956									
June 22	Male	2+ to 4+	200±	20.0	78	22	18.5	10,098,000	6,500
July 5	Male	2+ to 4+	165	4.0	44	48	16.0	..	..
August 9	Male	2+ to 4+	207	3.6	59	32	15.5	..	9,400
October 15	Male	2+ to 4+	200±	..	64	28	19.5	..	5,250
1958									
July 11	Female	5+ to 8+	161	..	63	5	16.5	..	17,900
Zoo bears									
1956									
September 15	Male	½	34	..	76	20	14.5	..	11,950
October 12	Male	2½	200±	..	..	32	11.0	..	8,050
1958									
April 19	Male	2½	125±	..	84	4	18.7	10,280,000	13,650

* Per 100 white blood cells.

on other bears because they usually voided urine before it could be collected, and in none of the bears was a urinary lesion observed or suspected. All specimens were negative for white and red blood cells. A trace of albumen was noted in each. Specific gravities of two specimens were 1.033 and 1.012. No casts, sugar or bile were found in these samples.

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FACTORS IN HATCHERY POND DESIGN[1]

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ABSTRACT

Three aspects of pond design were investigated as applied to rectangular rearing ponds, i.e., water circulation, water aeration, and screen size. It was found that for best circulation the inlet and outlet should be the same width as the pond. Any of the tested modifications of a simple dam at pond outlets improved aeration. A flat rack with its upstream edge on top of the dam was one of the most effective aeration devices. Screen areas sufficient to provide 1 square foot of usable (underwater) screen for each 25 gallons per minute flow are recommended.

Three aspects of the design of rectangular hatchery ponds, i.e., water circulation, water aeration and screen area were investigated and the results are presented under these topics. Several minor features of pond design are also discussed.

WATER CIRCULATION

The study of pond circulation was based on statements of O. R. Kingsbury, both in his paper (1951) and in private conversations. Briefly, he believes that the potential production of a trout hatchery may be estimated on the basis of the supply of spring water, and that production should be at least 40 pounds per year per gallon per minute of the spring-water supply. Further, the required pond space for this production may be estimated according to the rule that each cubic foot of rearing space should produce at least 2 pounds of trout per year. Kingsbury's data apply specifically only to ponds 2 feet deep.

Kingsbury also believes that in order to attain this production it is essential for the rearing facilities to be so designed that, in a given unit, each cubic foot of water is as nearly as possible like each other cubic foot. This requires ponds of essentially uniform depth with straight sides. It also requires an even flow of water through any cross section of the pond. With good fish-cultural practices, if the requirements of good circulation and even depths are met, the fish will use all parts of the pond equally, the tendency for different habits in various parts of the pond will be eliminated, growth will be at a maximum, and even growth of all fish will be promoted.

Poor water circulation in hatchery ponds probably has many physiological and biological effects on fish. Two effects on the water chemistry have been observed. First Brockway, personal communication and as reported by Phillips *et al.* (1949), studied the accumulation of metabolic products, as measured by ammonia, in series of ponds. In addition to a

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-11-R.

[2] Now a graduate student at Cornell University.

general increase in the concentration of ammonia as tests were made from the head to the foot of the series, he found spots in each pond where the concentrations were higher than average. He termed these "hot spots", and concluded that they were almost certainly caused by uneven circulation of the water.

A second example of the effect of poor circulation was observed at the conclusion of the series of pond-aeration tests reported here. After a good means of increasing aeration had been developed, such a device was installed on the dam at the foot of one of the large "Bath" type ponds—a type of pond in which the circulation is poor. Oxygen levels were measured above and below the dam both with and without the device in place. On successive trials the measured rise in oxygen as water passed over the dam varied erratically from 0 to 0.5 p.p.m. and no difference could be correlated with the presence of the aeration device. In order to study this phenomenon, a series of oxygen samples were taken, all above the dam and about 1 foot upstream from it. Three duplicate samples were taken at the water surface, one on either side of the 6-foot spillway and one in the center. Corresponding samples were also taken from points 2 feet below the water surface. These samples varied erratically, the maximum observed difference being 0.7 p.p.m. Evidently the uneven water circulation caused greater depletion of the oxygen in those parts of the pond where the circulation was poorer.

It appears quite possible that the differences in ammonia accumulation and oxygen depletion due to poor circulation may be important deterrents to optimum growth and health of fish.

Four types of rearing ponds are in use in New York State fish hatcheries.

1. "Bath" type (Figures 1 and 2). Two sizes are in use. One is approximately 50 feet long by 15 feet wide by 2 feet deep and the bottom is flat except for a slope of about 3 inches from end to end. Its volume is 1,250 cubic feet. The other is of the same proportions but considerably larger, being 100 feet long, 30 feet wide and 3 feet deep with a volume of 7,100 cubic feet.
2. "Rome" type (Figure 3). The dimensions are the same as in the Bath type, and except for the inlet and outlet the two are identical. The Bath type is "throated" at the ends with 3-foot spillways, while the Rome type with three spillways at the inlet and at the outlet approaches a design in which the inlet and outlet would occupy the entire width of the pond.
3. "Dirt" ponds. These are 60 feet long by 12 feet wide by 15 inches deep. They have sloping sides and the inlets and outlets are 3 feet wide. The cross section of these ponds is that commonly called "dish-shaped".
4. Circular ponds. This type was not included in this study.

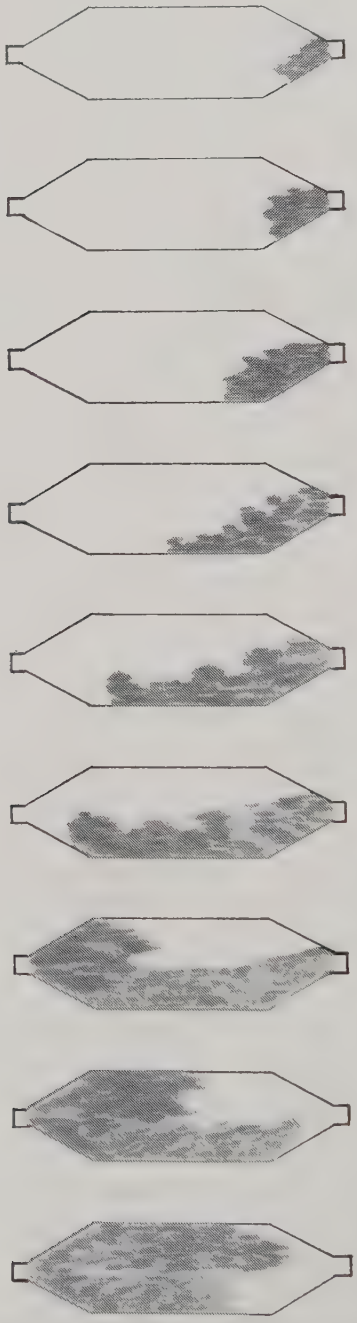

Figure 1. Pattern of water circulation in small "Bath" type hatchery pond as indicated by dyed inflow. Sequence is from top to bottom; waterflow, from right to left.

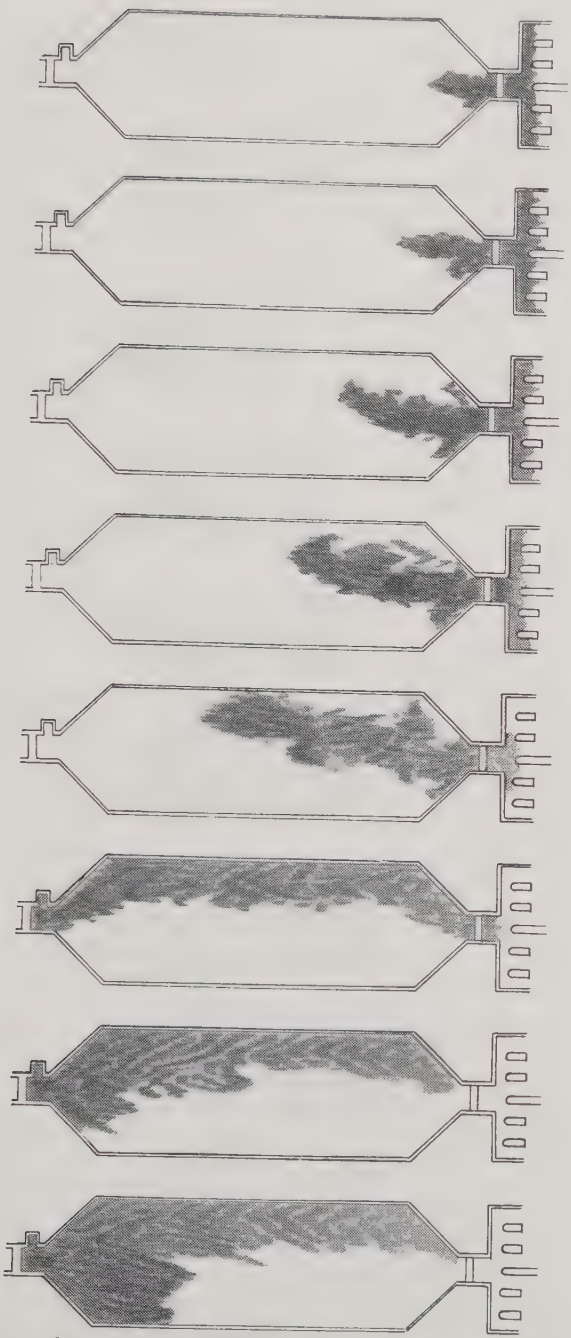

Figure 2. Pattern of water circulation in large "Bath" type hatchery pond as indicated by dyed inflow. Sequence is from top to bottom; waterflow, from right to left. (Scale two-thirds that of Figure 1.)

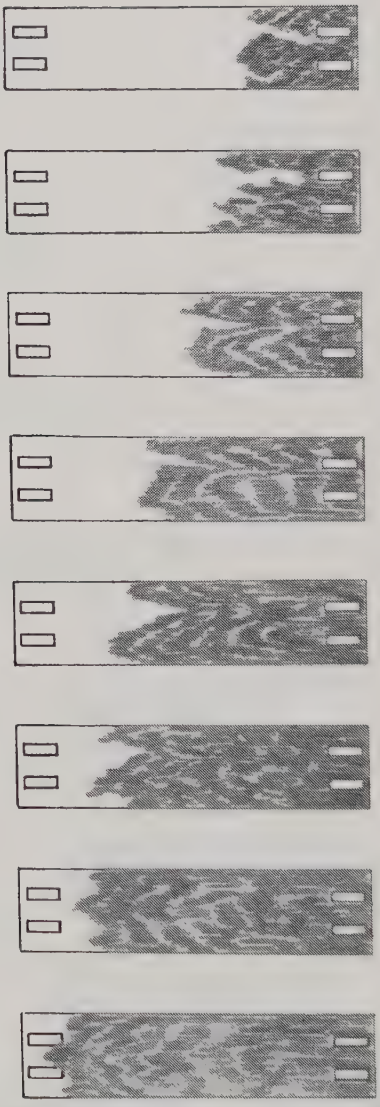

Figure 3. Pattern of water circulation in "Rome" type hatchery pond as indicated by dyed inflow. Sequence is from top to bottom; waterflow, from right to left. (Scale same as that of Figure 1.)

Tests were made in each of the first three types to determine the water circulation. For this, fluorescein dye was mixed with water and poured evenly across the foot of the pond above the test pond. During the time required for the fluorescein to pass through the test pond, colored photographs were taken at intervals. The results for the small Bath type pond are given in Figure 1, for the large Bath type pond in Figure 2, and for

the Rome type in Figure 3. Examination shows clearly that the Rome type most nearly approached an even circulation, and the conclusion seems warranted that, for best circulation in this type of pond, the inlet and outlet should be the full width of the pond.

Historically, it is interesting that rearing races 4 feet wide, about 30 feet long and 1 foot deep, were in the 1920's and 1930's found very unsatisfactory for small fingerlings. The inlets and outlets were about 1 foot wide. Recently the same type of raceway, but with an inlet and outlet of full width, has proven very satisfactory.

In the study of the large Rome type pond, it was repeatedly noted that the fluorescein, as it entered the pond, always moved toward the right side. It was finally discovered that a large valve, on a by-pass line which was located in the spillway on the left side just below the dam, so obstructed the water as to direct the flow to the right. By putting the boards in another slot below the valve the effect of the valve was reduced and the fluorescein went down the center of the pond. The circulation obtained was no more even than before, but at least it was symmetrical with respect to the pond width since the major current was in a narrow strip down the center. The obvious conclusion is that, for even circulation, one of the requirements is that spillways at the inlet and outlet should be symmetrical and free of obstructions.

No results from the dirt type pond are given because the photographs were poor. However, the circulation was, if anything, poorer than for the other types.

WATER AERATION

In a series of rearing ponds, in which the water is used several times, the oxygen content of the water often is a limit of capacity. The oxygen content in the lower pond of the series depends on (1) the oxygen of the water supply feeding the head of the series, (2) the amount of oxygen removed by the fish and (3) the amount of oxygen added to the water by aeration as it passes from pond to pond. Since, ordinarily, the dissolved oxygen in the water supply is not controllable, maintenance of adequate oxygen in the lower ponds of the series depends primarily on the aeration which occurs as the water falls over the dams at the end of each pond. It is, therefore, of great importance that the dams be designed to produce the maximum aeration possible.

This problem was suggested by low oxygen in certain ponds at the Rome Hatchery. In a series of four ponds with only 4 inches fall from pond to pond, the aeration was known to be small. These ponds were about 15 feet wide. They had three spillways at the inlet, each 40 inches wide, so that the total dam length was 10 feet (Figure 3). The flow through the pond series was 500 gallons per minute. Two similar series side by side fed into the head of a series of four ponds (Figure 2) in which

the flow was, therefore, 1,000 gallons per minute. This lower series of four ponds had only 8 inches drop between ponds. They had single 6-foot spillways at the inlets and outlets. Annually in September, with high temperatures and heavy fish loads, the oxygen content of the water in the last pond was very low. The problem was whether changes in the dams would increase the aeration. Three questions needed to be answered.

1. In the upper ponds would the aeration be better or worse if the flow were confined in one spillway instead of three?
2. Would flat screens on top of the dams in the upper ponds reduce or increase the aeration?
3. Would some modification of the dams in the lower ponds increase the aeration?

Tests were made at the outlet dams to evaluate variables including (1) height of fall, (2) depth of water below the dam, (3) flow per unit length of dam and (4) devices added to the dam either to increase aeration or for some other purpose, such as screens or racks at the crest to prevent fish jumping over the dam.

Methods

During July and August of 1958, one of the water supplies (lake water) of the Rome Hatchery had an oxygen content of about 4 p.p.m. Using this supply and a rectangular concrete pond, a series of tests were made in which the fall, depth of water below the dam, and flow per unit length of dam were varied. The efficiency of aeration was determined from the increase in oxygen as the water passed over the dam, as measured by comparing the oxygen content of the water above and below. After a considerable number of tests had been made, it was found that the aeration provided by a single fall was so small that the differences between the effects of 6-inch and 12-inch falls could not be measured with enough accuracy to be of use. The results, therefore, indicated general trends, but provided no reliable detailed information.

To increase the accuracy of the measurements, a modification of these tests was conducted using an oxygen atmosphere over the dam instead of air. A dam, 1 foot in width, was built in a hatchery raceway, with provision for varying the height of fall, the depth of water below the dam, and the flow. To this was added a hood which covered the dam and an area above and below it, and which dipped into the water on all sides to provide a water seal. In this hood the air atmosphere was replaced by oxygen. At the beginning of each test, the water level in the raceway was raised so as to flood the hood. Oxygen was then introduced at a rate of 1 cubic foot per minute; the hood had distributed small leaks so that the oxygen flow could escape. This rate of flow was sufficient to change the entire air volume about once every 12 minutes.

Tests were made with the oxygen atmosphere for varied conditions of fall, flow, depth below dam, etc. Since the percentage efficiency of aeration, in terms of the oxygen content of the water, equals

$$\frac{\text{actual rise}}{\text{possible rise}} \times 100$$

these results may be converted to the equivalent values for air aeration by the following two equations.

$$(1)\ \text{percentage efficiency} = \frac{B - A}{S - A} \times 100$$

$$(2)\ \text{expected rise} = \frac{\text{percentage efficiency} \times (S - A)}{100}$$

in which,

A = oxygen content above dam
B = oxygen content below dam
S = saturation value

For example, if $A = 4$ p.p.m., $B = 5$ p.p.m., and $S = 10$ p.p.m., then

$$\text{percentage efficiency} = \frac{5 - 4}{10 - 4} \times 100 = 16.7$$

In this hypothetical case the aeration raised the oxygen content of the water 1 p.p.m. or one-sixth of the maximum amount that would be possible with perfect aeration.

Air is approxmately one-fifth oxygen, so that the saturation value for an oxygen atmosphere is 4.85 times that for air. Thus, in the foregoing example, the equivalent aeration in air would be derived from the second equation, in which $A = 4$ p.p.m., $S = 48.5$ p.p.m., and percentage efficiency = 16.7, as follows:

$$\text{expected rise} = \frac{16.7 \times (48.5 - 4)}{100} = 7.4 \text{ p.p.m.}$$

Increasing the value for the rise in oxygen content from 1 p.p.m. to 7.4 p.p.m. by this means results in greater accuracy in determining efficiency. It also permits experiments with water that is high in oxygen by normal standards of air aeration. The results of such experiments may be applied to air aeration by the use of the equations given.

For calculating the results of the experiments, the saturation values listed in Table 1 were used.

The first tests evaluated the efficiency of a simple dam such as is used at the outlet of many hatchery ponds. Although the crest of such a dam is usually shaped according to the edge of the lumber used, all of this series were made with a sharp-edged crest (as used in a weir for measuring waterflow), the crest consisting of the edge of a thin sheet of iron.

Table 1. Values for Saturation of Oxygen as Used to Determine Efficiency of Aeration

Temperature in degrees F.	Saturation value (p.p.m.)	
	Air atmosphere	Oxygen atmosphere
45	12.1	58.7
46	11.9	57.7
47	11.8	57.2
48	11.6	56.3
49	11.5	55.3
50	11.3	54.8
51	11.2	54.3
52	11.0	53.3
53	10.9	52.9
54	10.8	52.4
55	10.7	51.9
56	10.5	50.9
57	10.4	50.4
58	10.3	50.0
59	10.2	49.5
60	10.0	48.5

Effect of Height of Fall

Tests were made for falls varying from about 3 inches to 12 inches, and the results are shown in Figure 4. Aeration increases as the fall increases and appears to be approximately proportional to the fall. Thus two 6-inch falls are approximately equivalent to one 12-inch fall, and conversely one 12-inch fall produces twice the aeration of a 6-inch fall.

Effect of Depth of Water below Dam

The effect of the depth of water below the dam is shown in Figure 4. It appears that, for flows of 25 to 100 gallons per minute per foot of dam length and for falls of 4 to 15 inches, the depth of water below makes little or no difference. When the depth of water below the dam is zero, or as nearly so as possible, the aeration is very greatly reduced. "Zero" depth will be discussed later.

Effect of Flow per Unit Length of Dam

Tests were made using flows of 25, 50 and 100 gallons per minute per foot of dam length. The results are shown in Figure 5. The differences were not great, so that it seems to matter little whether the flow is spread over a wide dam or concentrated in a narrow one. A flow of 50 gallons per minute per foot of dam length was somewhat less efficient than 25 or 100. Since the reason seems obscure, this point was checked repeatedly, and the results were consistent.

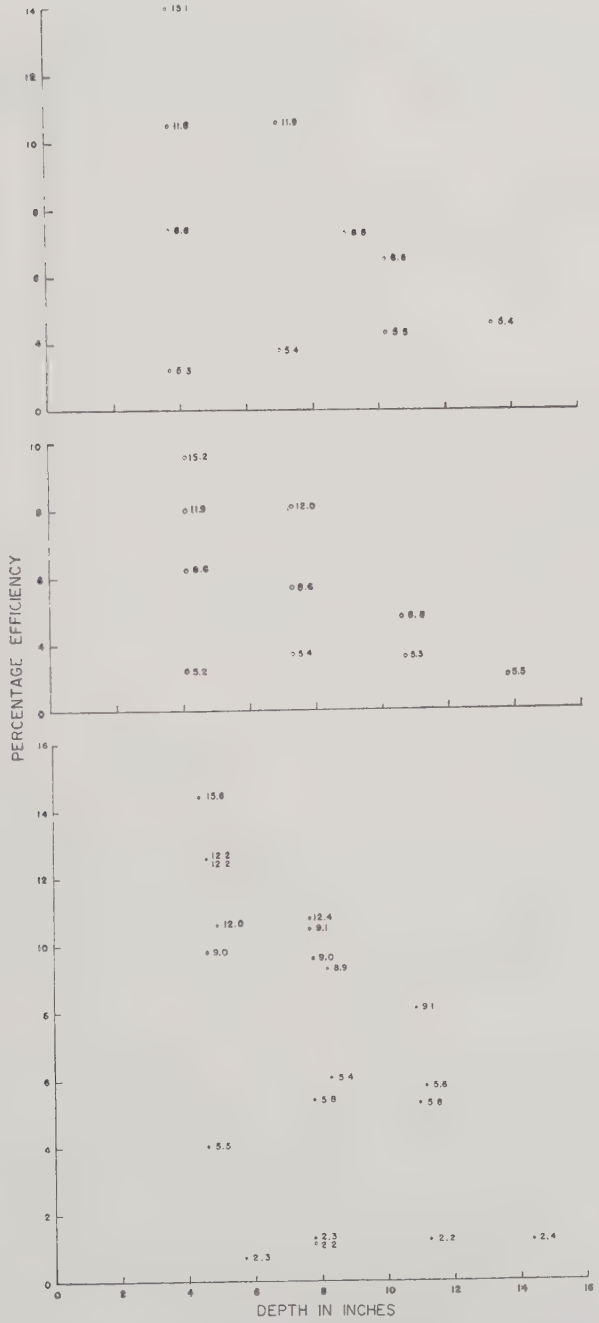

Figure 4. Comparative efficiency of aeration for a simple dam in relation to depth of water below dam for three rates of flow: (top) 25 gallons per minute; (middle) 50 gallons per minute; (bottom) 100 gallons per minute. (Figures opposite plotted points represent fall in inches.)

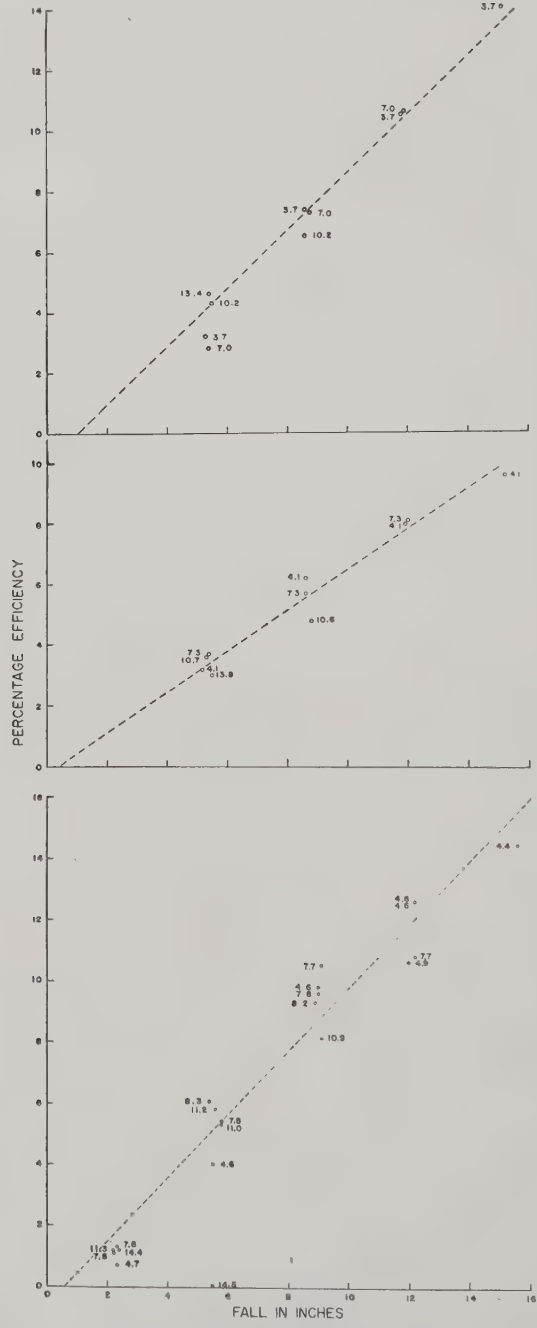

Figure 5. Comparative efficiency of aeration for a simple dam in relation to height of fall for three rates of flow: (top) 25 gallons per minute; (middle) 50 gallons per minute; (bottom) 100 gallons per minute. (Figures opposite plotted points represent depth in inches of water below dam.)

MODIFICATION OF A SIMPLE DAM

The remainder of the tests led to the conclusion that any modification of a simple dam improves aeration. They were made with a flow of 50 gallons per minute, a fall of 8.6 inches, and a 4-inch depth of water below the dam. These conditions probably are typical of many hatchery situations where aeration is inadequate. Although the efficiency of a simple dam was not greatly affected by differences in the rate of flow, over the range of the tests, it is likely that such differences may considerably affect the efficiency of some of the modified dams.

ZERO WATER DEPTH BELOW DAM

In the experimental set-up used, it was impossible to get a water sample below the dam when the water was falling into the empty raceway. Therefore, to simulate such shallow-water conditions, a small wooden platform was placed below the dam with its surface ¼ to ½ inch above the water (Figure 6).

Water samples were collected through the board just below where the water hit it, and aeration was found to be small (Table 2). However, samples taken from the raceway below the board showed a marked increase in oxygen content. Observation indicated that the falling water did not splash as it hit the board, but rather flowed off the board in a rapid, thin sheet and hit the raceway water with a high horizontal velocity. Tests confirmed that this motion produced an aeration of up to 14 per cent, the amount varying with the height of the flat surface above the water surface below. Having the flat surface about ½ inch above the water surface appeared best.

It appeared that any method which would convert the momentum of falling water into horizontal velocity, shearing the surface of the water below and creating turbulence, would produce good aeration. Several arrangements of chutes were tried, and produced values up to 11.7 per cent depending on the exact arrangement. One of these devices is illustrated in Figure 7.

DEVICES PLACED ON DAM

Many hatcheries use a rack or screen placed on top of a dam with one edge over the dam and the remainder extending out level on the downstream side. These are normally employed to prevent fish from jumping up over the dam. The efficiency of several such arrangements (Figures 8–10) as aeration devices was tested. The results are included in Table 2. The finer the screen the greater the efficiency and, by the same token, the screens were more efficient when somewhat plugged with dirt. The flat rack with slats spaced ¼ inch apart was more efficient than any of the screens, in fact it was the most efficient device tested. Its efficiency was 15.8 per cent at a flow of 50 gallons per minute, 17.7

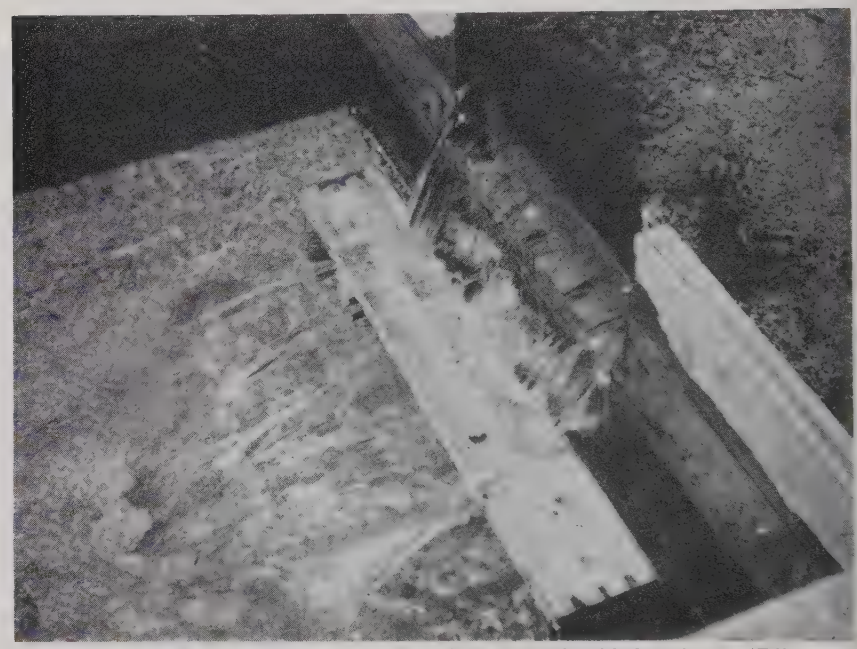

Figure 6. Simple dam with flat board just above water level below dam. (Efficiency 14.1 per cent.)

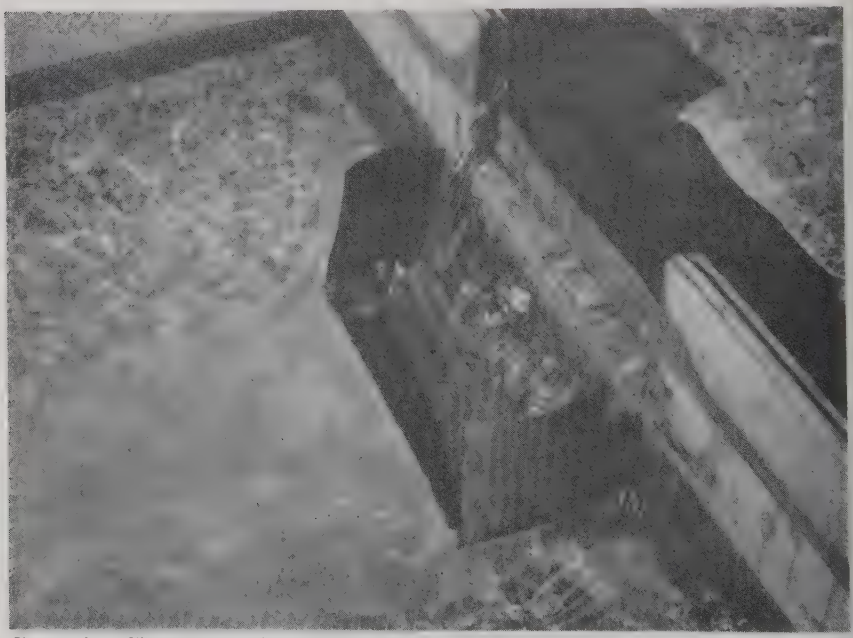

Figure 7. Chute to produce high horizontal velocity below dam. (Efficiency 11.7 per cent.)

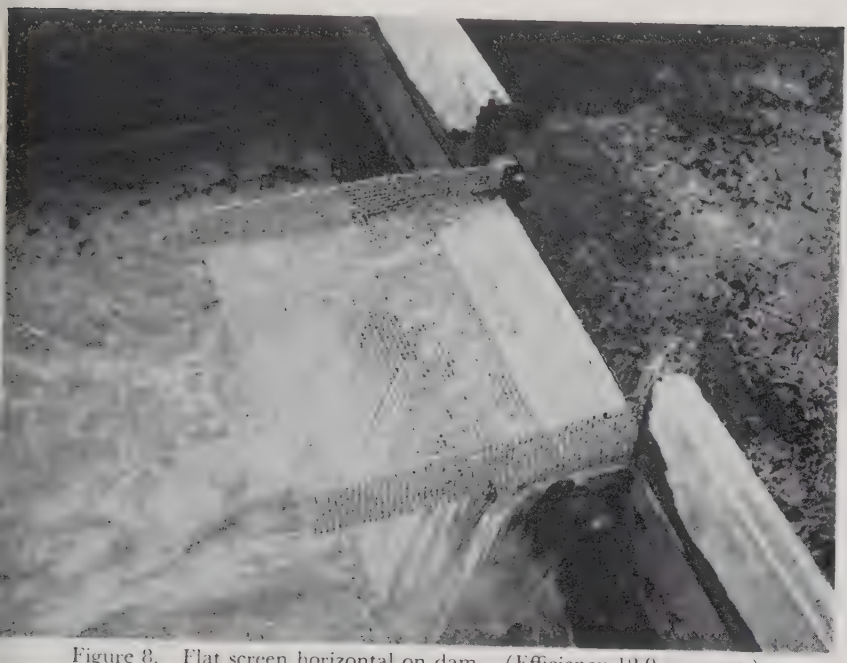

Figure 8. Flat screen horizontal on dam. (Efficiency 12.9 per cent.)

Figure 9. Flat rack horizontal on dam. (Efficiency 15.8 per cent.)

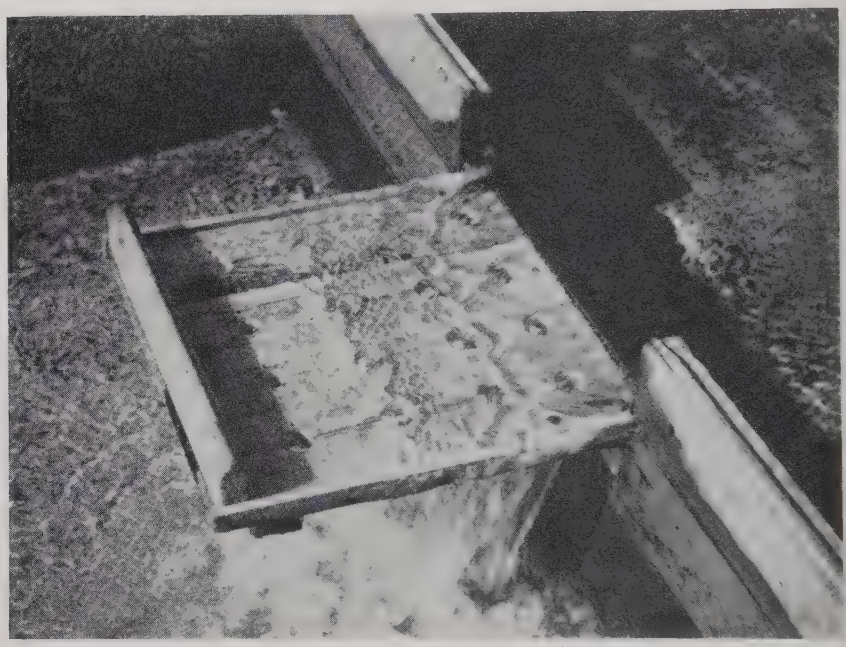

Figure 10. Flat board, with holes, on top of dam. (Efficiency 15.6 per cent.)

per cent at 25 gallons per minute, and 14.4 per cent at 100 gallons per minute. With this type of rack it is important that the slats be wide enough, in this case ¾ inch, to prevent the streams of water through adjacent slots from immediately recombining.

Table 2. Comparative Efficiency of Aeration for Various Modifications of a Simple Dam*

Efficiency in per cent	Modification
6.2	simple dam
0.5	narrow board just above water level, sample taken through board
14.1	narrow board below dam
11.7	chute below dam
13.7	⅛-inch-mesh flat screen, dirty
15.1	window screen
12.9	¼-inch-mesh, flat screen
15.8	flat rack, ¼-inch spacing
8.8	flat sheet metal on top of dam
15.6	flat board with 16 1-inch holes
10.8	rockpile below dam
14.6	vertical rack
12.5	vertical board with four rectangular holes (1 inch wide by 1½ inches high) 2⅝ inches apart
11.0	vertical board with four slots 1 inch wide by 3¼ inches high
13.5	vertical board with seven 1-inch holes

* Waterflow was 50 gallons per minute; height of fall, 8.6 inches; depth of water below dam, 4 inches.

It was theorized that, if the horizontal velocity of the water were increased before it started to fall, the aeration might be increased. To test this, a chute or trough was placed on top of the dam to raise the velocity of the water. The resulting efficiency of 8.8 per cent was not impressive.

Another device tested was a flat piece of ¾-inch plywood placed on top of the dam with 1-inch holes bored through it in sufficient numbers to accommodate the waterflow. This is illustrated in Figure 10. Its efficiency of 15.6 per cent at a flow of 50 gallons per minute was essentially the same at a flow of 100 gallons per minute provided the board size was increased and the number of holes made sufficient to handle the increased flow.

Since racks, etc. placed horizontally on top of a dam were effective, tests were made to determine the results with the same devices set on top of the dam vertically (Figures 11–13). In general, they provided quite good aeration, particularly the rack and board with holes which was nearly as effective as when placed horizontally.

ROCKPILE BELOW DAM

In line with the widely accepted theory that "breaking water up" provides effective aeration, a "pile of rocks" was placed below the dam and the water hit on this while still falling through the air. Its rather

Figure 11. Vertical rack on top of dam. (Efficiency 14.6 per cent.)

Figure 12. Vertical board, with slots, on top of dam. (Efficiency 11.0 per cent.)

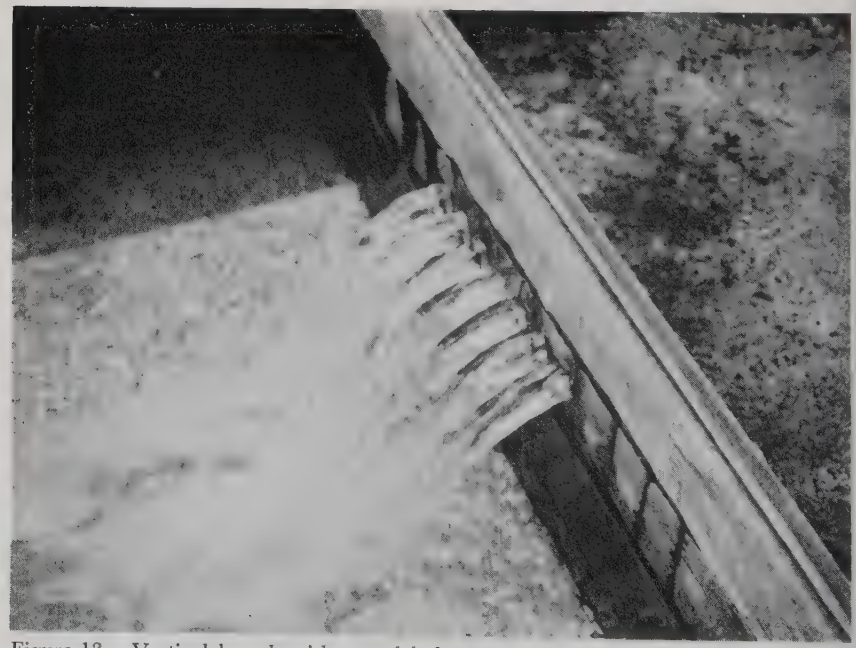

Figure 13. Vertical board, with round holes, on top of dam. (Efficiency 13.5 per cent.)

low efficiency of 10.8 per cent indicated that this is not a particularly good aeration method, at least in the arrangements used here.

SCREEN AREA

An important factor in pond design is provision for adequate screen area at the head of ponds in a series. Inadequate screen area increases the labor of cleaning enormously and even contributes a hazard to survival of the fish. On the other hand, experience indicates that screen area can be too great, so that debris is not actually drawn to the screen in a degree which facilitates its removal.

The various ponds at the Rome Hatchery, as well as some that have been reconstructed in varied designs, have permitted observations on the efficient screen areas for different degrees of flow. These may be summarized briefly. Defining "working screen area" as the area under water during normal conditions, then a good ratio of working screen area to flow is 1 square foot for each 25 gallons per minute. Greater flows per square foot can be tolerated, but in one group of ponds with a flow of 85 gallons per minute per square foot the screen was quite inadequate and required continuous maintenance except under extremely favorable conditions. In another series of ponds, 60 gallons per minute per square foot proved somewhat inadequate.

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USE OF CLOSED CONIFER PLANTATIONS BY WILDLIFE[1]

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ABSTRACT

To obtain specific data on the relationship of wildlife to conifer plantations a summer study was made of the birds and mammals in a 256-acre closed plantation of red pine, white pine and Norway spruce on the Tully Forest. Ruffed grouse was the principal game species. Chickadees, robins, black-throated green warblers and towhees were common in the plantation. Information was also gathered on various mammals including deer and cottontail rabbits.

Grouse used the outer 5 chains of the plantation as long as other good habitats adjoined it. Where old hedgerows, scattered apple trees, hardwood clumps or brushy openings occurred within the plantation, grouse were found in the vicinity. There was a tendency for the grouse to use the plantation more during the middle of the day and at night, but to move to surrounding habitats during the morning and late afternoon.

Results support the principle that, where game is an important consideration, large plantations of conifers should be broken up with openings that will provide an interspersion of brushy cover.

Large areas of pure, dense, conifer plantations with closed canopies have been severely criticized as wildlife habitat. Most criticism has been based largely on general observation, the actual value of such plantings to wildlife having received little intensive investigation. This paper is the result of a field study of closed conifer plantations as wildlife habitat.

Reforestation with coniferous species was one of the earliest forest practices given wide application in the United States. Although the planting of large areas was most pronounced between 1934 and 1938 as influenced by the work of the Civilian Conservation Corps, a resurgence is now occurring which is being greatly accelerated by the Soil Bank program. For instance, in New York, the production of conifer seedlings in State-operated nurseries is expected to be about 60 million by 1961.[2] This total will exceed the number distributed during 1935, a peak year of Civilian Conservation Corps activity (Baar, 1956). Similar trends are evident in other eastern and midwestern states.

It is apparent that the conifer plantation will be a major forest element in the United States for at least several decades. Eventually, some of these on the heavier soils will be converted to hardwood stands; but most of those on the lighter soils, which are better suited to the production of conifers, will be retained as coniferous stands. With an increased

[1] The authors acknowledge the assistance given by members of the faculty and graduate students of the Department of Forest Zoology and by the staff of the Tully Forest throughout the project.

[2] E. J. Eliason, N. Y. S. Cons. Dept., personal communication, 1957.

understanding of soils, soil-water relationships and the specific requirements of trees, many foresters now believe that repeated crops of conifers might be harvested from medium-textured soils. Therefore, the conifer plantation appears to be a permanent part of American forestry, presenting many new problems in forest management and silviculture.

It has been generally assumed that, during the first few years following planting in an open area, the presence of the young trees has little effect upon wildlife. However, as they gain dominance in the vegetation, the added cover of the conifers may result in great alterations in both the numbers and kinds of wildlife present. As the plantation reaches an age of from 15 to 25 years, the crowns begin to form a closed canopy. The degree of closure depends upon the species of conifer involved and on the spacing of the trees. In plantations that have attained almost complete crown closure, very little light penetrates the overstory and almost no herbaceous plants can exist in the understory, except in openings which may or may not be common. Beneath the canopy the plantation becomes a tangle of living and or dead branches, almost impenetrable to man and many animals.

The lower branches are either pruned naturally or removed in stand improvement as the trees approach commercial size. Later, when the tree heights reach 50 feet or more, additional light filters through the canopy, particularly if thinning operations have recently occurred. An understory of herbaceous plants and hardwood seedlings usually develops and, on many areas, a hardwood forest will eventually result unless conifers are again established by artificial means at considerable expense.

It is the intermediate stage, i.e., the closed stand of conifers with little or no understory, that has caused greatest concern among wildlife biologists. The general opinion that such stands are of little value as wildlife habitat is well illustrated by their widespread designation as "biological deserts". Few specific evaluations have been made, however, of conifer plantations as wildlife habitat.

Bump (1950) noted the need for conifer plantings to furnish shelter for game on an area of predominantly abandoned and overgrown farmland in New York. However, the value of overly large, pure stands of conifers to wildlife was questioned by Deem (1938), Chapman (1947), and especially by Edminster (1935). Gray and Hermel (1939) investigated the interspersion of natural openings within a large reforestation area in Michigan, and Smith (1958) made an extensive survey of the habitat characteristics of a great variety of conifer plantations in New York.

Some comprehensive studies of the birdlife within conifer plantations in England have been reported by Mackenzie (1945, 1949, 1952), Lack (1933, 1939) and Lack and Lack (1951). Smith (*op. cit.*) also included information concerning birdlife in various kinds of conifer plantations in New York.

Most reports of mammals in conifer plantations have concerned damage to the trees. Use by deer of a conifer plantation in Massachusetts was described by Hosley and Ziebarth (1935).

PLANTATION : WILDLIFE RELATIONS

Reference to closed conifer plantations as "biological deserts" could be misleading, for certainly even the most sterile-appearing, pruned stand of pine is not completely devoid of wildlife. Yet it is true that the large, solid plantations with closed overstories support only a limited number and variety of animals, especially game species. This seems to be the result of three factors: (1) the characteristics of the pure, dense conifer plantation as a plant community; (2) the inherent characteristics of the wildlife concerned; (3) the size of the plantation in relation to the needs of the animals. Of these, only the latter is within man's control.

Characteristics of Closed Plantations

Conifer plantations with closed canopies lack the variety that is associated with natural stands. Most are of a single species and age class, and they support very little, if any, ground cover. Openings within them are often infrequent. This condition provides little variety in the kinds of food and types of cover available to animals. Therefore, such stands offer only a limited number of possible combinations of food and cover to meet the needs of animal populations. There is also less variety in the chemical, physical and psychological environment. As a result, fewer kinds of animals are associated with conifer plantations than with natural and more varied plant communities (including naturally-occurring pure, even-aged forests).

It is important to note that the homogeniety of conifer plantations is becoming even more pronounced. Foresters are now better able to select the proper tree species for each planting site; planting methods have been improved recently; and future prospects call for more intensive plantation management in the form of pruning, thinning and cleaning. There is great need for a better understanding of how wildlife management can be integrated with silvicultural practices to improve wildlife habitat in these plantations.

Characteristics of the Wildlife

Conifer plantations are a relatively new and different plant association throughout many parts of temperate North America. The few extensive pure stands of conifers which do occur naturally in these regions are seldom as pure or as dense as the artificially established plantations. Moreover, although planting conifers has been long practiced in this country, most of the reforestation has been done within the last 30 years. Thus, it is probable that some new habitats for wildlife to occupy have

been created and that some of them are as yet unfilled. There are three ways in which such niches become filled.

1. Often animals are so generalized that they are preadapted to new environments. Thus, some species may make immediate use of large, closed conifer plantations as soon as they develop.
2. Given sufficient time, characteristic varieties (not new species) of animals may evolve to occupy empty niches in new environments. Therefore, future adjustment of present wildlife forms could, in time, result in an increased use of conifer plantations.
3. Widespread alterations in the vegetative character of an extensive area may attract new species into the region. This is range extension and is most obvious among the birds which, due to their high mobility, often make a sudden appearance. Range extension in mammals, however, occurs more gradually and may be associated with evolutionary adjustment. In this manner, animals requiring coniferous vegetation might extend their range into areas where the planting of conifers has been extensive.

SIZE OF THE PLANTATION

It is well known that many kinds of wildlife, especially game species, require the interspersion of several cover types in their environment, and that a greater interspersion of the necessary cover types usually results in a greater abundance of animals on an area. The solid conifer plantation, therefore, is only a part of the total habitat of most wildlife species, the animals traveling between two or more cover types to fulfill their needs.

The distance to which a species will penetrate a given cover type is limited by two factors. First, it must travel at least far enough to fulfill those requirements for which it entered the type. Second, it will penetrate no further than a distance which is determined by its inherent cruising radius. If the quality of the cover type (with respect to these requirements) is optimum, the animal may fulfill its needs with very little penetration. In this case, as the population density increased, competition for those requirements furnished by the type would also increase and would result in greater penetration and a more complete use of it. If other requirements of the species were equally available immediately outside the type, complete use could proceed up to the limit determined by the animal's cruising radius. Under such conditions the entire area of the cover type would contribute to the size of the animal population as long as its diameter was not more than twice the cruising radius of the animal.

This is a highly theoretical situation and would not occur in nature due to characteristics of both the habitat and the animals. Very few, if any, cover types supply an animal's needs throughout their area to such an optimum degree, and other needs not supplied by the type in

question will not be so ideally available. Most requirements will be available in varying degrees in more than one cover type, and their availability will fluctuate seasonally.

From the animal standpoint, the needs of a species are altered by seasonal and even daily weather changes. Also, the basic psychology of an animal may inhibit its penetration into a type, as happens when an individual enters an open area in search of food, but will not travel far from available escape cover. All these factors affect the penetration of animals into a cover type and, therefore, will affect the value of that type in increasing the abundance of the animals.

This reasoning may be applied to conifer plantations. Consider a wildlife species on a typical reforestation area. Since a large proportion of the land in such areas is usually planted, those needs of the animal which are satisfied by coniferous cover probably would be overabundant. The number of animals that the area could support would then be limited by the amount and interspersion of other vegetative types.

The amount of area in these non-coniferous types usually cannot be increased appreciably, for wildlife production is not the prime purpose of most reforestation areas. However, if their interspersion within the planted areas can be improved, higher animal populations should result.

The obvious question is, "How frequently should these other units of cover be interspersed among the conifers?", or "How large should the individual blocks of pure coniferous cover be?" The answer, of course, is related to the amount of consideration given to wildlife production. But the reaction of animals to increasingly larger blocks of conifers may be most important.

The factors governing the penetration of wildlife into cover types may limit rather definitely their use of large blocks of conifers. If the animals do not penetrate beyond a certain distance into a plantation, planting a reforestation area to blocks of conifers above a certain size limit would usually result in a lower abundance of animals than would a pattern of smaller units. In such cases, imposing any limit on the size of the blocks would be a matter of weighing the value of the forest products against that of the wildlife.

This investigation was designed to determine some of the factors that influence the distribution of wildlife within large, closed conifer plantations, and also to gather information on the penetration of certain species into such plantings from adjacent habitat.

THE STUDY AREA

A large, closed conifer plantation located on the Tully Forest was selected for study. It was chosen because it was convenient and typical of plantings which are termed "biological deserts". It is the largest of several closed plantations on the Forest.

Tully Forest, a 2,400-acre property of the State University College of Forestry at Syracuse University, is located in Cortland County about 25 miles south of Syracuse. The topography of this region is somewhat rugged, being typical of the margin of the Appalachian Plateau. Like much of the southern uplands of New York State, most of the Forest area had either been cultivated or pastured for several decades and later abandoned. Ultimately, a large portion of it was planted to conifers by the State. It became a property of the College of Forestry in 1949 and today consists of about 37 per cent hardwoods, 39 per cent conifer types (almost entirely plantation) and 24 per cent reverting fields, pastures, orchards, roadsides and abandoned home sites.

The specific plantation chosen for study consisted of 256 acres of red pine (*Pinus resinosa*), white pine (*Pinus strobus*), Norway spruce (*Picea abies*) and small amounts of white spruce (*Picea glauca*) and larch (*Larix* sp.). An aerial photograph and a type map are presented in Figures 1 and 2. The planting was composed mainly of three tracts: one of red pine, one of white pine and one of a row-by-row mixture of Norway spruce and white pine. The shortest dimension across the center of the area was about 25 chains (1,650 feet), and the narrow extension on the western end of the planting was 18 chains (1,188 feet) across in the area studied. The blocks of the various conifer species were not intermixed in a manner that would create an interspersion of types within the plantation itself; but there were some hedgerows and small patches of hardwoods in the area.

The red pine and white pine stands were planted in 1931 and were 26 years old at the time of the study. The mixed stand of Norway spruce and white pine was one year younger. All were about 35 to 40 feet in height.

Some silvicultural treatment, indicated in Figure 2, had been applied to a few interior plots in the red pine stand. This pruning, light thinning, and cleaning did not result in any noticeable response in the ground cover. Generally, there was very little ground cover in this closed stand, except in scattered openings which were fairly common along the southern edge. Apple, thornapple and cherry trees were scattered among the pines and occurred more frequently along the southern edge.

The white pine stand in the center of the plantation had been heavily damaged by weevils, resulting in its having a low commercial value. Some widely spaced row thinnings had been applied to about three-fourths of the stand to improve accessibility. Ground cover, mostly a thin growth of *Rubus*, was scattered throughout, but was more abundant where the row thinnings provided extra light.

Norway spruce and white pine were planted in alternate rows on the third part of the plantation. There was almost no herbaceous growth in the understory, and the ground litter was constantly moist. The

Figure 1. Aerial photograph of the study area, a portion of the Tully Forest. Scale: 1 inch equals 1,667 feet.

humidity was usually higher within this stand than in surrounding areas. Although some row thinnings had been made more than 10 years before the study, the trees had already formed a dense canopy over these cuttings. The tendency of the spruce to retain its branches to the ground made movement through this stand most difficult.

Most of the area was surrounded by brushy, overgrown pasture or stands of hardwoods in which some blowdown had occurred. On one edge, a still-used pasture bordered the plantation. The entire study area was relatively level.

METHODS

Line transects, here referred to as observation lines, were used for gathering data. Their locations on the study area are indicated in Figure 2. These lines were divided into 5-chain sections, each section being designated by a code number. They were lightly brushed to permit easy walking.

The longest observation line, called the "center line", followed an

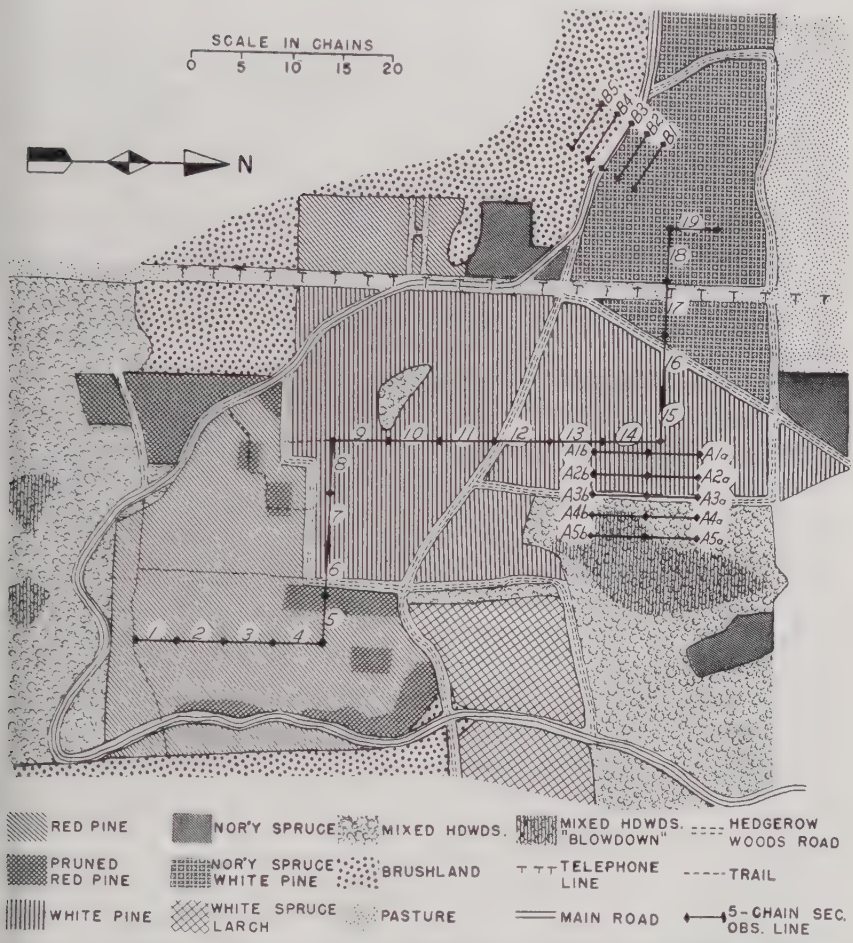

Figure 2. Type map of the study area showing the location of the observation lines.

irregular course through the interior of the plantation. It encountered many features which commonly lend variety to the vegetation within large conifer plantations, and also sampled areas where the planting was quite homogeneous. In addition to the center line, two units of observation lines (A and B in Figure 2) were designed to measure the occurrence of wildlife near the edge of the plantation. Each contained five parallel lines, the middle one at the edge of the planting and others at distances of 2 and 4 chains (132 feet and 264 feet) on either side. These units were thus half in the conifer plantation and half in the adjacent cover type. The lines in Unit A were each 10 chains long; those in Unit B, 5 chains long.

Intensive field work, the results of which are reported here, was done during July and August of 1957. Wildlife species were observed and

trapped, and other evidence of their presence was noted, along the lines at frequent intervals. All records of wildlife were noted according to the section of line on which they occurred. The time and date of each observation were also noted. All animal sign present at the beginning of the study was excluded from the data. On subsequent visits, all sign was recorded and removed to avoid duplication.

Records of grouse included birds flushed and the presence of such sign as droppings, feathers and dusting bowls. Whole broods were occasionally encountered, but were considered as a single observation in the final analysis of the data. Observations of other species of birds were also recorded.

Information concerning the distribution of mammals on the area was obtained principally through the use of baited live-traps. Small-mammal trapping was conducted, during periods of three nights duration, for a total of 1,002 trap-nights. In addition, larger live traps for such animals as raccoon, opossum and rabbit were used for 300 trap-nights.

ANALYSIS AND INTERPRETATION

The data were examined first for bias due to sampling procedure. Some tendencies which might have affected the results were noted and taken into account in the analysis.

Since all sections of the observation lines were not visited the same number of times, the number of observations of a species on each section was adjusted to a 30-visit equivalent so that comparison might more readily be made. This altered the data very little, for the average number of visits to all sections was 27.4.

The occurrence of some species was indicated by sign as well as by actual observation of the animals. It is to be expected that the amount of animal sign that would accumulate along an observation line would vary with the length of the study period. For the various line sections, the study period ranged from 37 to 59 days, the average being 49.6 days. It was desirable that the data for sign be combined with the data for observations of the animals before the results were evaluated. The amount of animal sign that was noted during the study period for each section was, therefore, adjusted to a 30-day equivalent, giving this type of data the same numerical basis as that for direct observations of the animals.

On any section of line the occurrence of those species for which both sight and sign records were obtained was then represented by the sum of these two indices. It is, in theory, the number of observations of both the animals and their sign that would have been noted if that line section had been visited daily for 30 consecutive days.

The results of small-mammal trapping were likewise adjusted to a 30-trap-night equivalent so that the catches on the many line sections might be compared more easily.

Since the data for ruffed grouse (*Bonasa umbellus*) are the most significant they are presented in detail; other species are discussed briefly.

RUFFED GROUSE

Although the Tully Forest was known to be carrying a high population of grouse during the time of this investigation, records were difficult to obtain for two reasons. First, the study included the moulting season when grouse are more secretive than at most other times of year, and second, it is believed that grouse use coniferous cover least during the summer. Nevertheless, 32 flushes and 66 instances of grouse sign were recorded.

The occurrence of grouse in the plantation appeared to fluctuate with the time of day. Only a few were observed in the conifers between 9 a.m. and 11 a.m. (EST). Then, in the early afternoon, the birds seemed to be common. Again, only a few grouse were flushed in the plantation during the late afternoon, but their frequency increased between 7 p.m. and 8 p.m. In the evening, the birds were usually flushed from the crowns of trees.

This apparent fluctuation in occurrence within the plantation throughout the day may have reflected the activity or "flushability" of grouse during various hours. It may also have been due to the movements of the birds. In the latter case, grouse may have been uncommon in the conifers during the late morning hours because they left the planted areas in search of food. At the beginning of the hottest part of the day, they returned to the cover of the conifers where the temperature was usually 3 to 6 degrees lower than in surrounding types. In late afternoon and early evening, the birds again tended to leave the plantation for food and to return again at dusk to roost.

This daily behavior pattern seems feasible for ruffed grouse on reforestation areas where food and shelter often are not well interspersed within the individual cover types. Bump *et al.* (1947) did not record this behavior. They suggested that the birds usually found food and shelter sufficiently interspersed within single units of cover, and therefore such movements were not necessary. The data on which their conclusions were based, however, applied to only a negligible degree to reforested areas such as that discussed here.

The occurrence of grouse on the study area, as indicated by the combined indices from both flushes and sign records, is presented in Table 1, and their distribution in Figure 3. The results for adjacent sections of observation line are in fair agreement with each other, and trends due to changes in the degree of occurrence are usually continuous along the lines. Therefore, the results seem to be a valid indication of grouse distribution on the area. In the following discussion of the data and their relation to features of the study area, references to the various

line sections will be made according to the code numbers in Figure 2, "C" being used to designate the center line. Four points relative to

Table 1. Distribution of Observations for Ruffed Grouse

Line section	Index*	Remarks
		Red pine
C 1	2.6	Small openings; apple and thornapple trees
C 2	0.6	Stand interior; little ground cover
C 3	0.6	Stand interior; little ground cover
C 4	0.0	Stand interior; little ground cover
C 5	1.6	Borders hedgerow, partly pruned and cleaned
		White pine
C 6	5.0	Crosses hedgerow; near another hedgerow
C 7	2.5	Hedgerow 1 chain away
C 8	2.5	Hedgerow 1 chain away
C 9	2.7	Near hedgerow and patch of hardwoods
C10	1.9	Near patch of hardwoods
C11	0.6	Stand interior; scattered ground cover
C12	1.3	Crosses fire lane
C13	2.8	5 chains from hardwood stand
C14	3.0	5 chains from hardwoods with blowdown
C15	2.5	Mountain ash and apple trees
C16	1.0	Crosses hedgerow
A 1a	0.0	Stand interior; near closed hardwoods
A 2a	1.2	Near edge; adjacent to closed hardwoods
A 1b	3.4	Stand interior; near blowdown
A 2b	3.6	Near edge, adjacent to blowdown
		Norway spruce—white pine
C17	4.0	Narrow part of stand; hedgerow and right-of-way
C18	2.1	Entering large, dense stand
C19	1.1	Stand interior; very little ground cover
B 1	4.1	Stand interior; very little ground cover
B 2	8.2	Near edge; large apple tree (used as roost)
		Non-coniferous
A 3a	0.6	Road; no understory; adjacent to closed hardwoods
A 4a	0.0	Closed hardwoods; little understory
A 5a	0.6	Closed hardwoods; little understory
A 3b	1.2	Road; no understory; adjacent to open hardwoods
A 4b	3.1	Open hardwoods; dense undergrowth and ground cover
A 5b	5.9	Open hardwoods; dense undergrowth and ground cover
B 3	1.6	Road; hardwood border; little cover in understory
B 4	3.3	Interspersed openings, brush, aspen and balsam
B 5	4.3	Interspersed openings, brush, aspen and balsam

* Represents number seen and sign converted to 30-visit equivalent. Number of visits for each line section was the same as listed in Table 2; the sign recorded, however, was accumulative for the periods between visits.

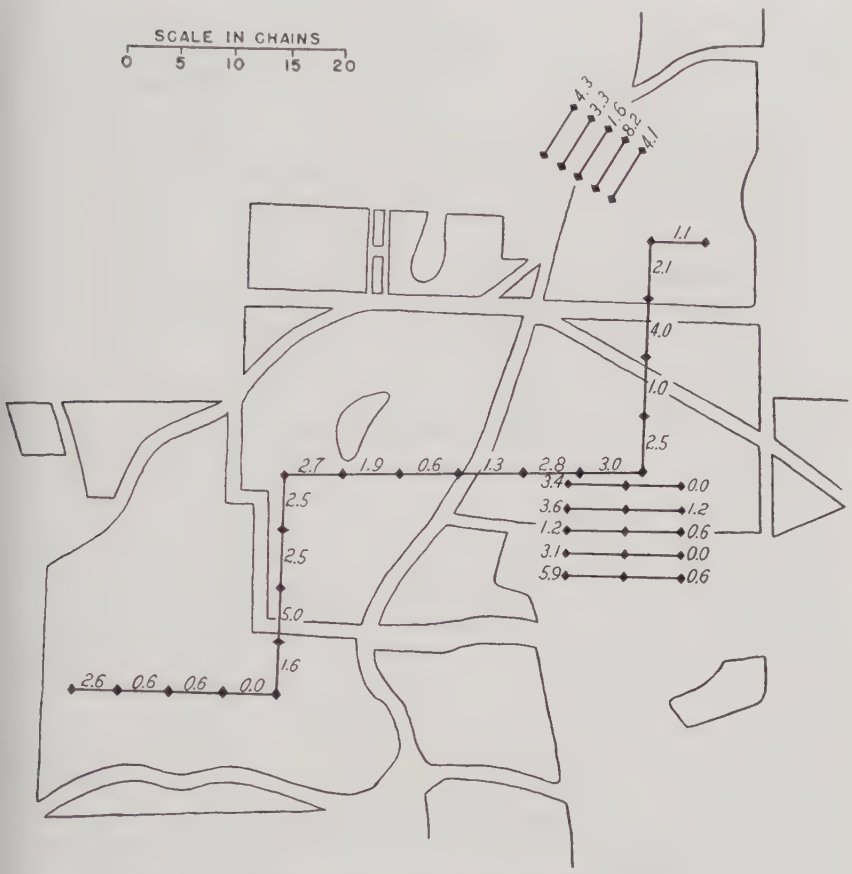

Figure 3. Indices of ruffed grouse distribution on the study area.

the summer distribution of ruffed grouse within and around this large closed conifer plantation seem important.

(1) The data indicate that during the summer ruffed grouse seldom use the interior of large, solid stands of planted conifers with closed canopies. Very little evidence of the birds was found deep within the plantation where wide brushy hedgerows, frequent small openings, patches of hardwoods, or clumps of apple, thornapple or mountain ash trees did not occur. This situation was evident in Sections C2, C3, C4 and C5 in the red pine stand, in Sections C10, C11 and C12 in the white pine and in Section C17 in the Norway spruce-white pine. All these line sections were well within the conifers and, except for Sections C11 and C12, were isolated from vegetative features that would lend variety to the habitat. The indices of grouse occurrence on these sections were among the lowest obtained in the study. The exceptions in Sections C11 and C12 are discussed under (3).

(2) It is also evident that the occurrence of grouse deep within large plantations may be greatly increased by the presence of such features as wide brushy hedgerows, patches of hardwoods, frequent openings or scattered fruit trees within the stand. This was evidenced by the relatively high grouse-occurrence index for Section C1 where scattered apple trees and small openings occurred in the red pine stand, and especially by the indices for Sections C6, C7 and C8 where the observation line ran near a wide brushy hedgerow. The index was also high for Section C9 parts of which were near the hedgerow and a patch of hardwood trees. Even the occurrence of grouse on Section C10 seems to have been somewhat influenced by the nearness of the hardwood trees.

On Section C15 in the interior of the white pine stand, the index was also fairly high. Grouse seem to have been attracted to a small patch of mountain ash along this section of line. Further, the highest index recorded on the study area occurred where a large apple tree stood among the Norway spruces and white pines along Section B2. Apparently, the birds roosted in this tree almost every night.

Section C17 traversed the narrow part of a small, triangular-shaped stand of Norway spruce and white pine. This part of the plantation was bordered on one side by a telephone right-of-way with herbaceous vegetation, and on the other side by a brushy hedgerow. Its high occurrence index of 4.0 indicates that grouse favored this combination of a narrow conifer planting bordered on two sides by a variety of deciduous vegetatation.

(3) Not all breaks in the continuity of the plantation were attractive. A wide grassy fire lane, crossing the observation line near Sections C11 and C12, did not seem to attract many grouse to that part of the plantation. There was also a low occurrence index on Section C16 where the observation line intersected a brushy hedgerow. The low indices for these two situations which might have been expected to attract grouse may have been due to one or more of three factors.

First, some quality which was attractive to the birds, but not obvious to the investigator, may have been lacking in these areas.

Second, there may have been a more attractive area nearby, e.g., one that offered a greater variety of grouse food and/or cover. This appeared to be the case along the open fire lane near Sections C11 and C12. There was considerable shrub and tree vegetation on other nearby parts of this fire lane, but none where it intersected the observation line.

Third, the low grouse-occurrence indices in these two situations may have been due only to sampling error. This could well have been the case for Section C16 where the index of 1.0 disagrees considerably with that of 4.0 for the next Section, C17. However, it seems evident that grouse were not attracted to *all* openings and other breaks in the continuity of the conifer plantation. The vegetative composition of such

breaks in a planted area is important in determining their attractiveness to ruffed grouse.

(4) The habitat quality of areas adjacent to a plantation will also strongly affect the occurrence of grouse within it. This is indicated in the data from both Units A and B along the edge of the plantation.

There were considerable differences in the character of the vegetation within the hardwood stand comprising Unit A as a result of large openings created by wind-thrown trees (Figure 2). Observation lines A4a and A5a were without the area of blowdown, while A4b and A5b were almost entirely within it. Further, the blowdown area was closest to the plantation at Section A4b.

Loss of a tree canopy in the blowdown area permitted a dense tangle of brambles (*Rubus* sp.) and sapling growth to develop; the resulting vegetation appeared to be an excellent summer food and cover area for grouse. This was quite in contrast to the rest of the hardwood stand which was mature and had a dense canopy, very little understory and little ground cover. The apparent difference in the habitat of these two areas is strongly substantiated when the grouse-occurrence indices for Sections A4a and A5a are compared with those for A4b and A5b. Grouse were commonly seen within the area of blowdown but seldom observed in the undisturbed part of the stand.

Figure 3 shows that the difference in the occurrence of grouse between these parts of the hardwood stand was reflected in their occurrence in the adjacent white pine plantation. Much more evidence of grouse was noted along those line sections nearest the blowdown area, even though the plantation was exceptionally homogeneous there. Thus, the frequency of grouse occurrence within the plantation seems to have been strongly influenced by the character of the vegetation immediately adjacent to it. In this case, where good summer grouse habitat occurred next to white pine, fair numbers of the birds used the conifers and penetrated at least 5 chains (330 feet) into the plantation.

There is an apparent irregularity in the data for Unit A, for the occurrence of grouse was least along the edge between the planting and the hardwood stand, i.e., along Sections A3a and A3b. The explanation appears to lie in the fact that large hardwood trees with broad crowns bordered the narrow dirt road which followed the edge of the planting. The shading of these trees precluded the growth of much understory or ground cover along this edge. As a result, there was very little cover for grouse. However, even along this edge, grouse were more commonly noted where the blowdown area was nearest the plantation.

Observations in Unit B tended to substantiate the conclusions reached for Unit A. A long-abandoned field, already in a successional stage of shrubs, young trees and scattered openings, was adjacent to the Norway spruce-white pine plantation. Clumps of aspen (*Populus* sp.), willow

(*Salix* sp.), viburnums (*Viburnum* sp.), dogwood (*Cornus* sp.) and balsam fir (*Abies balsamea*) were common there, producing excellent summer habitat. Grouse frequented this area, as indicated by the occurrence indices for Sections B4 and B5. Grouse were also common for a distance of at least 4 chains (264 feet) into the adjacent Norway spruce-white pine plantation (Sections B1 and B2). This indicates again that the habitat quality of areas adjacent to a conifer plantation will influence the degree to which grouse use it.

As in Unit A, evidence of grouse was least often noted along the plantation edge (Section B3), and the situation was similar. There were large, broad-crowned hardwood trees along the road bordering the plantation which resulted in a lack of cover near the ground.

In summary, the results of this work corroborate previous observations that some provision should be made for "breaking up" such large conifer plantations wherever the production of ruffed grouse is desired.

Other Birds

The greatest variety of bird species was found in the more open areas outside the conifer plantation, especially where blowdown had occurred in the mixed hardwood stand. Conversely, the least variety was found in the densest part of the red pine stand.

The black-throated green warbler (*Dendroica virens*) was the most abundant species in the plantation. Chickadees (*Parus atricapillus*) were common in all three conifer types, and thrushes (*Hylocichla*) were fairly common. Robins (*Turdus migratorius*), magnolia warblers (*D. magnolia*) and myrtle warblers (*D. coronata*) were seen most frequently in the Norway spruce-white pine stands where towhees (*Pipilo erythrophthalmus*) were also often found.

Ovenbirds (*Seiurus aurocapillus*), juncos (*Junco hyemalis*) and bluejays (*Cyanocitta cristata*) were seen occasionally; in the plantation they occurred most often in the white pine stand. Catbirds (*Dumatella carolinensis*) and flickers (*Colaptes auratus*) used brushy hedgerows within the plantation to some extent, but they as well as sapsuckers (*Sphyrapicus varius*) and woodpeckers (*Dendrocopos*) were virtually absent from the conifers although they were common in nearby hardwood stands.

Mammals

Sufficient information for comment was obtained for only a few mammals. Table 2 gives the distribution of the most common ones.

Red squirrels (*Tamiasciurus hudsonicus*) were one of the most conspicuous animals on the study area during the summer. They were about 17 times more abundant in the red pine stand than in any other cover type studied (Figure 4). This distribution seems to have been a response to food supply. The red pines were producing cones, while the

TABLE 2. DISTRIBUTION OF OBSERVATIONS FOR THE MOST FREQUENTLY RECORDED MAMMALS

Line section	Visits	Trap nights	Red squirrel		Chipmunk		Deer mice		Other mice*	
			Number	Index§	Number	Index†	Number	Index‡	Number	Index‡
Red pine										
C 1	23	30	18	23.5	4	4.3	4	4.0	—	0
C 2	23	30	20	26.1	1	1.3	2	2.0	—	0
C 3	26	30	24	27.7	—	0	3	3.0	—	0
C 4	26	30	17	19.6	—	0	3	3.0	—	0
C 5	31	28	42	40.6	—	0	1	1.0	1	1.0
White pine										
C 6	30	25	5	5.0	3	3.4	1	1.2	1	1.2
C 7	30	27	3	3.0	2	2.2	—	0	1	1.2
C 8	30	27	5	5.0	—	0	2	2.2	1	1.1
C 9	35	28	6	5.1	1	1.1	—	0	7	7.5
C10	32	26	1	0.9	—	0	—	0	8	9.2
C11	33	30	—	0	1	1.0	1	1.0	5	5.0
C12	33	30	—	0	2	1.9	1	1.0	1	1.0
C13	34	30	—	0	5	4.9	1	1.0	1	1.0
C14	40	45	2	1.5	1	0.7	2	1.3	4	2.7
C15	31	30	1	1.0	1	1.0	2	2.0	2	2.0
C16	29	28	2	2.0	8	8.4	1	1.1	—	0
A 1a	30	30	—	0	3	3.0	2	2.0	1	1.0
A 2a	25	30	1	1.2	—	0	1	1.0	—	0
A 1b	30	29	1	1.0	—	0	3	3.1	2	2.1
A 2b	30	30	3	3.0	—	0	2	2.0	2	2.0
Norway spruce—white pine										
C17	30	30	3	3.0	1	1.0	—	0	6	6.6
C18	28	30	—	0	1	1.0	2	2.0	7	7.0
C19	28	30	1	1.1	1	1.0	—	0	10	10.0
B 1	18	30	1	1.7	—	0	—	0	5	5.0
B 2	18	30	1	1.7	—	0	—	0	—	0
Non-coniferous										
A 3a	35	30	—	0	4	4.8	1	1.0	—	0
A 4a	23	29	—	0	5	5.4	4	4.1	—	0
A 5a	26	30	—	0	4	4.5	3	3.0	1	1.0
A 3b	25	27	1	1.2	2	2.1	2	2.2	—	0
A 4b	29	27	2	2.1	1	1.0	—	0	1	1.1
A 5b	25	29	2	2.2	1	1.0	1	1.0	—	0
3	19	26	3	4.7	—	0	4	4.6	1	1.2
4	18	30	—	0	1	1.0	—	0	—	0
5	17	31	—	0	2	1.9	—	0	—	0

* Represents red-backed mouse and meadow mouse.
§ Represents number seen converted to 30-visit equivalent.
† Represents number seen converted to 30-visit equivalent plus number trapped converted to 30-trap-night equivalent.
‡ Represents number trapped converted to 30-trap-night equivalent.

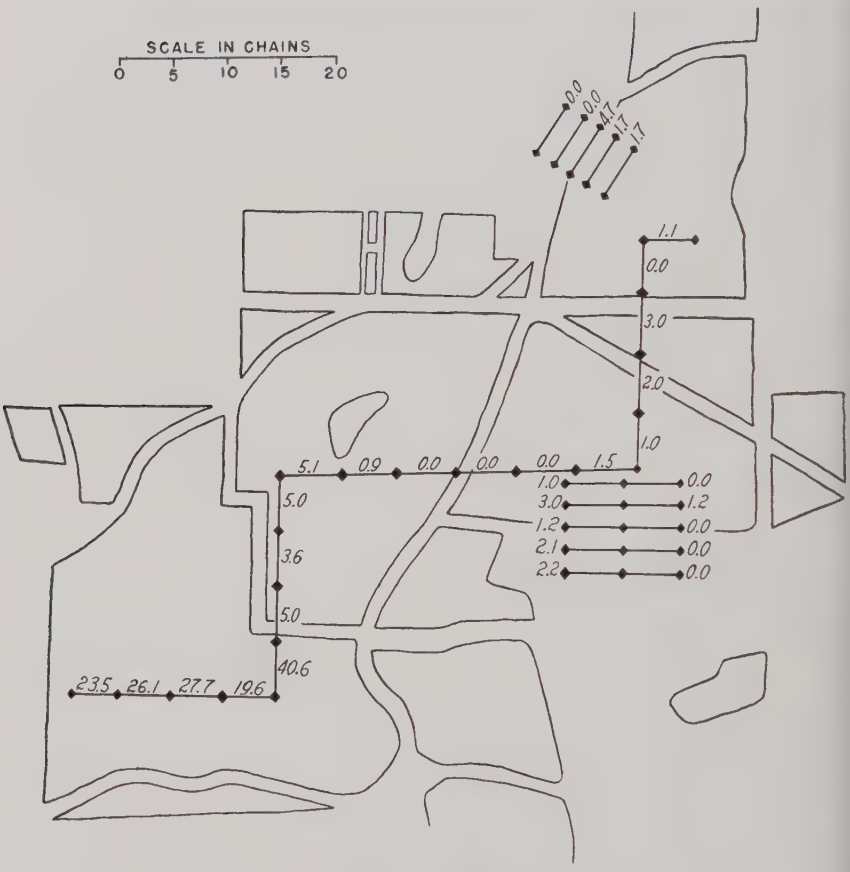

Figure 4. Indices of red squirrel distribution on the study area.

white pines produced almost none and the Norway spruce trees apparently produced very few. The presence of fruit- and seed-producing vegetation greatly affected the distribution of red squirrels elsewhere in the plantation also. In the other conifer types they were most often seen along brushy hedgerows and where the blowdown area of mixed hardwoods was closest to the planting.

Chipmunks (*Tamias striatus*) were found in all three important conifer types in the plantation. They were conspicuously absent, however, in the most homogeneous part of the red pine stand. This may have been partly due to competition from the great number of red squirrels in that area. Chipmunks were notably more common along moderately sloping ground; perhaps these areas were better adapted for ground burrows.

Deer mice (*Peromyscus*) were trapped in all principal conifer types of the study area. They were most common in the red pine although this stand supported very little ground vegetation. Deer mice were least

common in the Norway spruce-white pine stand and it is thought that a higher water table and more moist conditions in general may have made this area less desirable to them.

No distinction was made between the red-backed mouse (*Clethrionomys gapperi*) and the meadow mouse (*Microtus pennsylvanicus*) in this study. These mice were most common in the Norway spruce-white pine stand which was always moist. On the other extreme, only one individual was trapped in the red pine. Their distribution was irregular in the white pine although they were quite common in one part of this stand.

Manville (1949) noted a tendency for population densities of deer mice and red-backed mice to compliment each other. This situation was also strongly evident on the study area.

Cottontail rabbits (*Sylvilagus floridanus*) were abundant in the reverting fields and in the open conifer plantations which supported considerable ground vegetation. It was evident that rabbits seldom used the interior of large closed plantations during the summer. Also, few were noted along hedgerows within the conifers. It seemed that the openings within closed plantations would have to be quite large before they would be utilized by cottontail rabbits during this season.

No evidence of white-tailed deer (*Odocoileus virginianus*) was found more than 5 chains within the plantation, except where wide hedgerows or many small openings occurred. A fair amount of deer sign was noted in the white pine stand where some row thinnings had been made that created excellent travel lanes for these animals.

Raccoons (*Procyon lotor*) were trapped in the most interior parts of the plantation. However, since these animals often travel great distances to sources of food, it is possible that they were only passing through the plantation. They may also make use of abandoned ground dens commonly found in conifer stands.

Two opossums (*Didelphis virginiana*) were trapped deep in the plantation. All evidence of red foxes (*Vulpes fulva*) and woodchucks (*Marmota monax*) in the plantation was associated with brushy hedgerows. Smoky shrews (*Sorex fumeus*) were occasionally trapped in the white pine stand.

CONCLUSIONS

Coniferous cover is a valuable component of good wildlife habitat. A great variety of wild animals find some of their requirements in conifer plantations. However, the interior of large, solid plantations that have reached the closed-canopy stage is of limited use to most game species.

The extent of use by wildlife is determined by the size and shape of the plantation, species and spacing of the conifers, the associated neighboring habitats and the characteristics of the animals. A few species seem to find ideal conditions in plantations, but most obtain only part of their needs there. In summer, grouse will penetrate at least 330 feet into a

closed plantation. Animals with small radii of movement are generally limited by the type and amount of ground cover which are determined by the spacing and species of trees.

Where game is an important consideration, plantations should be interspersed with openings, brush and/or hardwood areas; conifer units should not be larger than 7 to 8 acres.

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QUANTITATIVE DETERMINATION OF COPPER IN A NATURAL RECEIVING WATER WITH 2,2′ BIQUINOLINE

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ABSTRACT

A rapid, accurate method for the colorimetric determination of copper in water is described, based on the purple-colored complex formed by the reaction of 2,2′ biquinoline (or cuproin as it is sometimes called) and the cuprous ion resulting from reduction with hydroxylamine. The complex is stable in a pH range of 5.3 to 6.0 and is easily extracted with a water-immiscible solvent. The technique is simple and rapid and it gives reproducible results under routine conditions. It is felt the procedure offers desirable advantages over the carbamate procedures.

Although sodium diethyldithiocarbamate and bis (2-hydroxyethyl) dithiocarbamate (known as cuprethol) have been used extensively for determining trace amounts of copper, both compounds have certain disadvantages. Lack of specificity, interference of other ions especially cations, instability of the copper complex, instability of the reagent in the case of cuprethol, and insolubility of the copper complex in the case of sodium diethyldithiocarbamate are the principal ones. These undesirable properties necessitate elaborate and sometimes unsatisfactory separation procedures for interfering ions, the use of stabilizing agents, and the frequent preparation of fresh reagent when cuprethol is used, and lead to color fading.

During a series of experiments at the Rome Pollution Laboratory concerning the toxic effect of copper on various species of trout, dissatisfaction with the carbamate reagents prompted efforts to find a better reagent. After an extensive search of the literature, 2,2′ biquinoline was selected as the most promising. Breckenridge *et al.* (1939), investigating coordination compounds, had reported the properties of the cuprous complex of 2,2′ biquinoline and stated the ligand to be specific for the cuprous ion and to form with it a purple-colored complex whose color intensity followed Beer's Law.

Hoste (1948) further investigated 2,2′ biquinoline (or cuproin as he called it) and reported that with it trivalent titanium gave a pale green color which could not be confused with the purple color of the copper complex. He listed 56 other cations which failed to produce a color with cuproin.

In 1950, the same author, after studying a number of reagents for copper, concluded that cuproin met all the necessary conditions, which he outlined, as a reagent for the quantitative determination of copper. In the same paper he described a quantitative cuproin procedure, using hydroxylamine hydrochloride as a reductant and extraction of the colored complex with a water-immiscible solvent. He concluded that extraction was complete in a single extraction at a pH greater than 3, but obviously

not high enough to cause the formation of insoluble basic copper salts. Thus the need for accurate control of pH was eliminated.

Hoste *et al.* (1950) continued studies of the application of cuproin to the problem of copper determination, particularly the effect of pH, cations and anions. They reported the maximum absorbancy at 546 mμ. They found the color to be stable in a pH range from 2 to 9, with a maximum error of 1.7 per cent at values from 3.05 to 9.0 and 0.52 per cent at values from 4.6 to 8.06. Concerning cations they studied the effects of the following in a ratio of 1,000 parts of the cation to 1 of copper and in the presence of 5 gamma of copper per milliliter of solution: Al, As, Ba, Ca, Cd, Co, Cr, Fe, Li, Mg, Mn, Mo, NH_4, Ni, Sb, Sn, Sr, Ti, V, W and Zn. Arsenic was present as the dibasic orthoarsenate, vanadium as sodium metavanadate, and tungsten as sodium tungstate. The other cations were present as the nitrate, chloride or sulfate of the metal. The greatest error, a positive one, was of the magnitude of 2 per cent and was due to cadmium which was present as the sulfate. Zinc, present as the nitrate, was found to produce a positive error of 1 per cent. Ferric iron and divalent nickel, present as nitrates, produced positive errors of 0.85 and 0.84 per cent, respectively. Titanium as the tetrachloride produced a positive error of 0.40 per cent. Trivalent antimony and divalent tin, present as chlorides, caused positive errors of 0.29 and 0.62 per cent, respectively. Arsenic, divalent manganese as the nitrate, and molybdenum produced slightly negative errors less than any of the positive errors noted.

The effects of the following anions were also reported: chloride, bromide, nitrate, sulfate, phosphate, perchlorate, acetate, oxalate, tartrate and borate, each being present as the sodium or potassium salt, except borate which was present as boric acid. No significant effects were noted except for oxalate which produced a negative error of 20.0 per cent when present in the ratio of 1,000 parts to 1 of copper and of 2.50 per cent in the ratio of 500 to 1. Cyanide, thiocyanate and iodide were reported as interfering, but no quantitative data on levels were given. The authors also noted that this reagent had been used for determining copper in water down to a level of 0.02 gamma per milliliter (0.02 p.p.m.), in steel alloys containing copper in a range of 0.01 to 0.1 per cent and in sugar beet ignition residues for a copper content as low as 2×10^{-4} per cent. The method was credited with an accuracy on the order of 1 per cent.

Concerning the effect of cyanide and thiocyanate, Maute *et al.* (1955) used cuproin to determine traces of copper in acrylonitrile. They reported that, in the presence of 0.40 p.p.m. of copper, 5 p.p.m. of hydrogen cyanide (present as sodium cyanide) produced no interference and that in amounts up to 50.0 p.p.m. it caused no interference if a minimum of 30 minutes were allowed for color development. A concentration of 50 p.p.m. or more would usually be recognized by its odor.

It might be pertinent to state at this point that, in the investigation

of fish kills in New York State, it is standard practice to confirm the presence or absence of cyanide and thiocyanate to levels of 0.10 p.p.m. or less by means of the highly sensitive Aldridge procedure.

Concerning the carbamate reagents, Woelfel (1948), in a paper which was the subsequent basis for many of the cuprethol procedures, reported the serious interference of cyanide. In fact, he went so far as to use this interfering property of cyanide to effect a separation of bismuth from copper by means of a differential technique wherein cyanide was used to destroy the color of the cuprethol-copper complex since the cuprethol-bismuth complex is unaffected by cyanide.

With respect to other applications of cuproin for determining copper, Cheng and Bray (1953) used it in analyzing soil and plant material, while Guest (1953) used it in metallurgical analysis and also studied the effect of pH as well as shaking time. Guest concluded that, with a copper concentration as high as 175 gamma, 30 seconds shaking time was sufficient as long as the pH was maintained between 4.4 and 7.5. He also reported the color of the complex to be stable for at least 1 week.

Butts *et al.* (1950) described a procedure for determining copper in water using cuproin but without extraction. They recommended a final pH of 2, using malonic acid, a value which is not supported by the work of Hoste, Guest and the present author. Considerable sacrifice of sensitivity might also be expected without extraction. No references or experimental data were furnished in the Butts paper.

PROCEDURE AND DISCUSSION

The cuproin procedure described here is used by the Rome Pollution Laboratory of the Conservation Department as a control method in experiments on the toxicity of copper. It is also used to obtain data for stream classification under provisions of the Water Pollution Control Law as well as to investigate possible contraventions of the recommended copper level of 0.2 p.p.m. prescribed in the standards set up under this law. The following reagents are required:

n-hexyl alcohol (Eastman No. P825) redistilled in glass

aqueous hydroxylamine sulfate or hydrochloride, 10 per cent weight/volume, prepared fresh daily

aqueous sodium acetate, 175 grams per liter

2,2′ biquinoline, 0.02 grams dissolved in 100 milliliters of redistilled hexyl alcohol

a standard copper solution prepared by dissolving 1 gram of spectrographically pure copper in redistilled nitric acid, boiling to expel oxides of nitrogen and diluting to 1 liter with copper-free distilled water

To an aliquot of the sample or a standard (10 milliliters in a 50-milliliter Maisel-Gerson reaction vessel if over 1 p.p.m., or 100 milliliters in a 125-milliliter separatory funnel if less than 1 p.p.m.) the following reagents are added in sequence with gentle mixing after the addition of each: 5 milliliters of the hydroxylamine reagent; 10 milliliters of the sodium acetate buffer; 10 milliliters of the biquinoline reagent, the latter being allowed to drain completely from the transfer pipet. Next the vessel or funnel is stoppered and shaken vigorously for at least 30 seconds. In the case of a 10-milliliter aliquot, the vessel may then be centrifuged at a moderate speed for 5 minutes. If a 100-milliliter aliquot was used, the funnel should be allowed to stand briefly and the aqueous layer withdrawn until the volume remaining in the funnel is about 45 milliliters. This remainder is then drawn off into a reaction vessel, stoppered and centrifuged. After centrifuging, the solvent layer is decanted into a cuvette and its absorbance measured at 546 mμ after the instrument has been zeroed (100 per cent transmittance or zero absorbance) against a reagent blank prepared with copper-free distilled water to establish calibration curves; in the case of an actual determination, a blank prepared from the sample plus reagents but substituting 5 milliliters of distilled water for the hydroxylamine reagent, or the sample, the reagents and n-hexyl alcohol if the reagents are known to be copper-free. Separate calibration curves should be established for both 10-milliliter and 100 milliliter aliquots. Calibration curves and determinations were made in this laboratory with a Bausch and Lomb Interference Filter Photometer using a filter with a peak transmittance of 546 mμ and 13-millimeter cuvettes. The curves obtained with this instrument are shown in Figure 1.

The solvent layer can be collected, redistilled and used again in preparing the biquinoline reagent. The pH of the aqueous layer should be checked occasionally; it should be between 5.3 and 6.0.

The color of the copper-cuproin complex was found to be quite stable for at least 24 hours under the conditions described.

N-hexyl alcohol was used as a solvent because of its greater insolubility in water combined with its lower volatility as compared with some of the more common solvents used in this type of extraction. If one suspects the presence of interfering amounts of cyanide or thiocyanide and the presence of these ions has not been previously ruled out, it might be well to return the solvent to the reaction vessel and determine the absorbance again after a lapse of 30 or more minutes, in which case shaking and centrifuging as previously described are suggested.

Because of the possibility of wide fluctuations in the pH of waters receiving industrial wastes, a study of the effect of pH was considered advisable. As Hoste had previously used sodium acetate-acetic acid as a buffering system, a similar system was set up and supplemented by

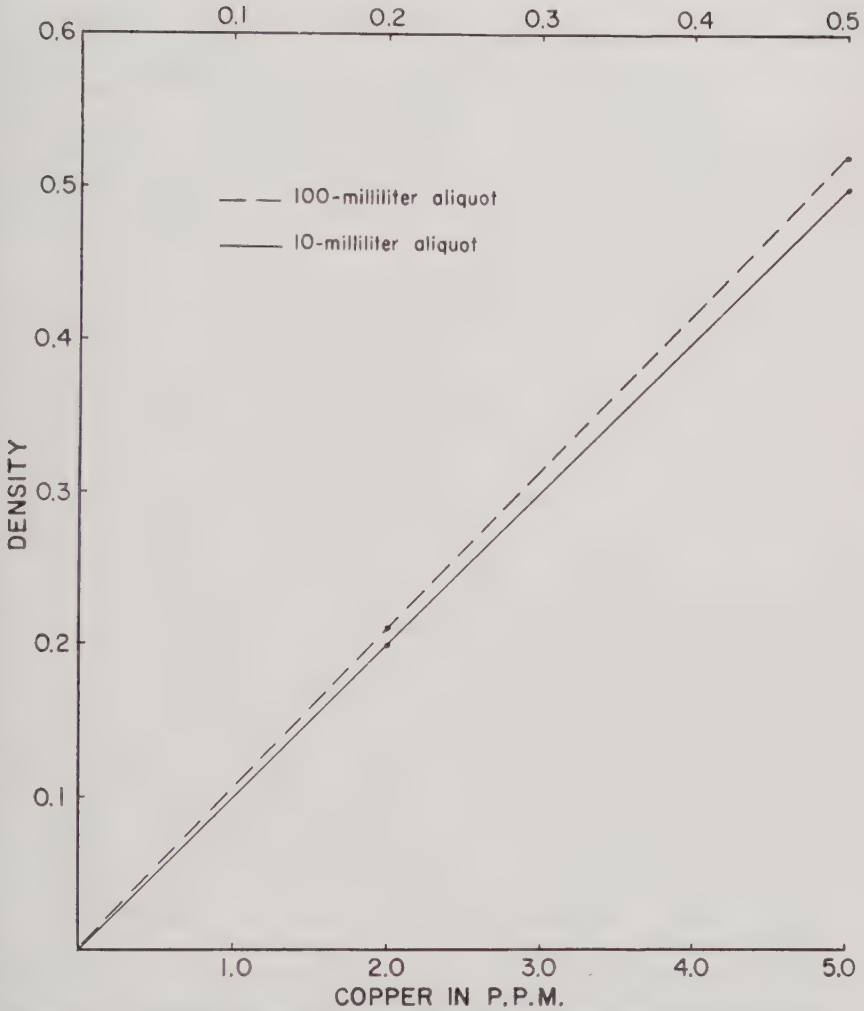

Figure 1. Calibration curves for copper. Use upper and lower indices of copper for 100-milliliter and 10-milliliter aliquots, respectively. (Density represented by $2 - \log_{10}$ transmittance.)

the use of a sodium acetate-sodium hydroxide system. The effect of pH is illustrated graphically in Figure 2.

The immediate density of the copper biquinoline complex in the hexyl alcohol layer was found to decrease with a reduction in pH, but to increase on standing. In the pH range of 5.3 to 6.0, the density change resulted in an error in the copper value of 1.6 per cent in 2 hours and 3.6 per cent in 24 hours when a solution containing approximately 5.0 p.p.m. of copper was used. At a high level of alkalinity (pH 11.7) a decided reduction occurred in the observed density from that obtained in what is considered the optimum range, i.e., pH 5.3 to 6.0. In 2 hours

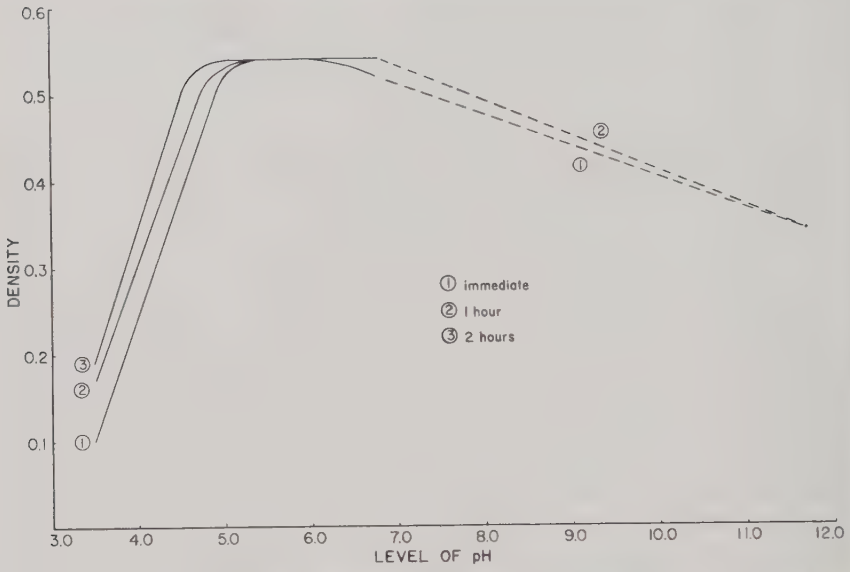

Figure 2. Effect of pH level on density of copper color complex; dotted lines are extrapolations to known value at pH 11.7. (Density represented by $2 - \log_{10}$ transmittance.)

at pH 11.7 the change in density produced an error of about 1 per cent in the copper value.

An attempt was made to compare the cuproin procedure described in this paper with that described by Butts *et al.* (1950) by extracting with hexyl alcohol the final solution obtained by their method. However, because of the extreme solubility of this solvent in the acetic acid solution obtained in their procedure (40 milliliters acetic acid in a final volume of 100 milliliters), no satisfactory comparison could be made.

The distilled water used in establishing calibration curves and in preparing reagents was considered to be copper-free when 500 milliliters were treated as previously described and no characteristic color of the cuproin-copper complex was visible in the solvent layer.

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GENERAL NOTES

WINTER FOOD HABITS OF PIKEPERCH IN ONEIDA LAKE

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Many investigations of the life history of the pikeperch (*Stizostedion vitreum*) have included food habits studies and these are well documented in fisheries literature. As a result, its food habits and diet preferences are fairly well known. Raney and Lachner (1942) made a very detailed study of the food taken by young (also some juvenile and adult) pikeperch in Oneida Lake and presented a rather comprehensive review of the literature on the food habits of this species.

Investigations usually have been made from specimens collected in the summer and fall. Eschmeyer (1950), Raney and Lachner (1942), Stone and Pasko (1946), and others have found that pikeperch are chiefly fish eaters, that they will take many species of fish if available, and that they will feed on yellow perch heavily when the perch are present in sufficient numbers. In all probability, yellow perch, although found to be the most common item in the diet, are utilized not because of preference, but simply by reason of availability in most waters.

During the winters of 1951–52 and 1952–53, an ice-fishing check was made on Oneida Lake and 143 pikeperch stomachs were examined. Of these, 112 (78.3 per cent) were empty, 20 (14.0 per cent) contained fish, and 11 (7.7 per cent) contained insect larvae. Foods identified in those stomachs containing food are listed in Table 1.

Table 1. Stomach Contents of 31 Pikeperch Taken by Angling in Oneida Lake During the Winters of 1951–52 and 1952–53

Food	Number of occurrences	Percentage frequency
Fish	20	64.5
Emerald shiner (*Notropis atherinoides*)	12	38.7
Yellow perch (*Perca flavescens*)	1	3.2
Golden shiner (*Notemigonus crysoleucas*)	1	3.2
Undetermined	6	19.4
Invertebrates	11	35.5
Mayfly larvae (*Hexagenia* sp.)	9	29.0
Undetermined	2	6.5

The percentage (78.3) for specimens containing no food was almost double that recorded by other workers who examined pikeperch from Oneida Lake during the summer and fall period. Raney and Lachner (1942) examined 65 stomachs from juveniles and adults and found 27, or 41.5 per cent, to be empty. Stone and Pasko (1946) found that 30, or 46 per cent, of 64 stomachs contained no food.

The nine fish found to have eaten mayfly larvae were checked on one day (February 2, 1952) from an area off the Cleveland harbor where there is a considerable amount of deep water over mud bottom; 12 others examined at the same time had empty stomachs. All 21 of these specimens were relatively small fish, ranging from 12.2 to 15.0 inches in total length except for one individual of 17.9 inches. Eleven were subadult or juvenile fish.

Another observation was that of the 20 pikeperch stomachs containing fish nine contained minnows that apparently had been used as bait. All were emerald (buckeye) shiners (*Notropis atherinoides*) that revealed definite hook scars in the vicinity of the dorsal fin. It is possible that other fish found in the stomachs had also been used as bait, but positive assignment to this category could not be made. It should also be noted that yellow perch appeared in only one stomach, though this has been reported to be a favorite food species of pikeperch in Oneida Lake at other times of the year.

[1] The data reported here were gathered while the author was employed by the New York State Conservation Department.

The high percentage of stomachs from Oneida Lake found to be empty during the winter is in contrast to that reported by Stroud (1949) for the Norris Reservoir in Tennessee where pikeperch taken in winter were generally well filled with gizzard shad. Dendy (1946) noted that striking intraseasonal growth rates suggest that forage species, while abundant in Norris Reservoir, may not be abundantly available at all times in the strata of water preferred by the pikeperch. In Norris Reservoir, the number of empty stomachs coincided with the movement of the pikeperch in early summer into deeper, cooler water where forage species were not readily available; at this time, growth rates declined. Thus, the absence of food in the stomachs of pikeperch in Oneida Lake (and possibly other waters) during the winter may be simply a matter of availability. Presumably very few food organisms occur in the habitat frequented by pikeperch during this period.

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SURVIVAL OF CARP AT A LOW TEMPERATURE[1]

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Twenty-two carp were held in a 350-gallon aquarium at 46° F. for continuous periods ranging from 254 to 499 days for different fish. The observations were made during experiments at the State Fish Laboratory at Livingston Manor (N. Y.) to develop methods for controlling carp. The availability of a constant-temperature spring afforded an opportunity to hold fish at this temperature for long periods. The spring flowed at a rate of 15 to 20 gallons per minute. A chemical analysis of this water (as of November 28, 1958) follows. Except for pH and specific resistance, all figures are in parts per million.

Oxygen (dissolved)	11
Carbon dioxide (as CO_2)	6
Methyl orange alkalinity (as $CaCO_3$)	10.8
pH (at 16° C.)	6.28
Total solids	23
Fixed solids	20
Calcium (as Ca)	5.50
Magnesium (as Mg)	0.98
Sodium (as Na)	0.46
Potassium (as K)	0.36
Sulphate (as SO_4)	5.3
Chloride (as Cl)	1.2
Fluoride (as F)	Nil
Nitrate (as N)	0.39
Nitrite (as N)	0.005
Ammonia (as N)	0.056
Silica (as SiO_2)	3.5
Phosphate (as P)	0.035
Total iron (as Fe)	Nil
Total Manganese (as Mn)	Nil
Copper (as Cu)	Nil
Zinc (as Zn)	Nil
Specific resistance (in ohms at 23° C.)	20,800

The fish were captured by electric shocker from two sources in the fall of 1958. Thirteen, weighing from about 2,000 to 4,000 grams and extremely fat, were taken from the lower Chenango River on September 30. Nine, weighing from about 500 to 800 grams and very thin, were taken from the Barge Canal near Waterloo on October 30. They were transferred to the aquarium on the same day in each case.

Food was not introduced into the tank at any time, but caddis flies and gross vegetation entered with the water supply. The maximum daily weight supplied from this source was 1.4 grams, but the actual amount was usually less. During the first 188 days for the Barge Canal fish and the first 218 days for the Chenango River fish this food was shared with 200 other carp. During the eighth month algae, including unidentified green algae and blue-green algae (Oscillatoria), began to grow as a slime on the sides and bottom of the tank. This growth contained filamentous desmids (Hyalotheca) and diatoms. These various foods were utilized to some extent (Table 1) and undoubtedly contributed to survival.

Because case histories of individual fish were not maintained, measurements of condition, relative weights, lengths, rates of metabolism, etc. are not available. The fish were sluggish but alert to outside stimuli throughout most of the period. The metabolic rates are assumed to have been low due to the low temperature and the effects of starvation.

Visual inspection of the fish did not reveal any pronounced emaciation. Examination of their internal organs after death revealed no obvious detrimental effects due to low temperature and starvation. All organs appeared to be normal. Ovaries and testes were full, although eggs were green. Little except visceral fat was present. Other observations have indicated that carp held at 46° F. often have various external injuries which do not heal readily. Transfer of such fish to water at 65° F. and a diet of trout pellets has facilitated healing within a week or two. Chronic lesions and abrasive injuries were present on all of the fish held during this experiment.

These carp were also subject to infestations of the protozoan Chilodon which

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R.

Table 1. Survival of Carp Held at a Temperature of 46° F. in a 350-Gallon Aquarium

Fish	Sex	Weight in grams at death	Days survived	Intestinal contents
		Chenango River*		
1	..	..	254	..
2	..	..	283	..
3	..	..	306	..
4	..	..	335	..
5	..	..	379	..
6	Female	2,100	434†	Filemantous algae (Oscillatoria); desmids (Hyalotheca)
7	Female	3,150	434†	..
8	Female	3,200	434†	Oscillatoria; Hyalotheca
9	Male	3,175	434†	Oscillatoria; Hyalotheca
10	Male	3,500	434†	Empty
11	..	..	446	..
12	..	..	481	..
13	Female	4,150	499	Dark green, bile-type liquid
		Barge Canal§		
1	..	..	236	..
2	..	..	323	..
3	..	..	356	..
4	Female	700	379	Empty
5	..	..	381	..
6	Male	700	404†	Insect sclerites and leg parts; Hyalotheca; green algae
7	Male	500	404†	Empty
8	Female	800	406	Bile colored, gelatenous material
9	Female	600	413	Crescent-shaped desmids; green algae; sand grains; sclerites

* Captured and placed in tank September 30, 1958.
§ Captured and placed in tank October 30, 1958.
† Died of suffocation.

formed a white film over the body. Infected fish became almost dormant, but recovered rapidly after treatment for 1 hour with a solution of 1 part formalin to 4,000 parts water. Treatments were necessary at intervals of about 2 months. Fish held at 65° F. after being taken from water at 46° F. often were infected at the time of transfer. One treatment was sufficient to cure these fish permanently. It is possible that carp held at low temperatures with little food are highly susceptible to this disease, at least in crowded aquaria. It is also possible that formalin is less effective against Chilodon at low temperatures.

During the period fish died at irregular intervals (Table 1). Death was usually preceded by several days of complete inactivity. Larger fish often died in an upright position.

On December 8, 1959 the 12 remaining fish (eight of the large fish from the Chenango River and four of the small fish from the Barge Canal) were treated for Chilodon infestation. An unfortunate accident resulted in the suffocation of five large and two small fish. Of these, the two small fish died within a few days, and two of the others died shortly thereafter. The last fish persisted for 2 months, having been held at a temperature of 46° F. for 499 days.

At the time of the accident the small fish had survived for 404 days; the large fish, for 434 days. Undoubtedly they would have survived much longer if the accident had not occurred. The five fish which survived for from several days to two months after the accident were uncoordinated in action until their deaths.

A METHOD FOR INTRODUCING CAPSULES INTO THE ALIMENTARY TRACT OF CARP[1]

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An efficient method of force feeding large carp was developed at the State Fish Laboratory at Livingston Manor (N. Y.). The technique was used to introduce No. 5 gelatin capsules filled with various chemicals into the upper intestine in order to determine their toxic qualities. To date, some 1,600 assorted chemicals have been force-fed to approximately 6,000 large carp (1 to 9 pounds). The actual operation is performed in less than half a minute.

Introduction is accomplished by using an aluminum tube fitted with a plunger. The tube is 9 inches long with an inside diameter of $\frac{5}{32}$ inch and an outside diameter tapered from $\frac{7}{16}$ inch to $\frac{9}{32}$ inch. A small, V-shaped, rounded groove is engraved on the first inch of the small end of the tube. When the tube is inserted, this groove engages a median crest on the basioccipital bone of the skull and is thus guided in a central position. A hilt prevents the fiber-glass plunger from extending more than ¼ inch beyond the end of the tube.

The accompanying illustration shows this tool in use. The end of the plunger can be seen in the X-ray just above the shot-filled capsule which lies in the esophagus. The esophagus leads ventrally from the pharynx to the forepart of the intestine (a stomach is lacking). The pharyngeal teeth are just anterior to the end of the tube and appear as vague roundish objects. The capsule must be pushed gently by the plunger to allow it to turn sharply into the esophagus. Two capsules may be fed in one operation of the plunger. Fish are held for the operation in a special device (Kelly, 1959).

For many fish, force feeding is relatively simple because direct access to the stomach may be had through the pharynx. Carp, other minnows and some other groups possess pharyngeal teeth which form an effective barrier to an ordinary probe. The aluminum tube used to feed carp must be forced past the grinding mill, formed by the pharyngeal teeth and the basioccipital bone, and into the thin-walled esophagus where the capsule is deposited. Care must be taken that the tube does not break or injure the teeth. If it or the plunger is inserted too far, the capsule may pierce the esophagus in the vicinity of the bile duct and be deposited in the pericardial cavity. Performed properly, the operation is almost always successful.

Variations of this technique may permit force feeding of or extracting secretions from fish of other species that possess pharyngeal teeth.

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R.

Side-view x-ray clearly shows the feeding tube forced past the pharyngeal teeth and the position of the shot-filled gelatin capsule in the esophagus. Large white areas represent two-chambered air bladder.

Errata

In the paper "Effect of Sevin upon the aquatic environment" by G. E. Burdick *et al.* (N. Y. Fish and Game Journal 7(1): 14–25) the grade of Sevin used was given incorrectly. On page 16 (line 21) the specification should read 85% pure.

In the paper "History of the white-tailed deer in New York" by C. W. Severinghaus and C. P. Brown (N. Y. Fish and Game Journal 3(2): 129–167) a typographical error occurred in Table 8. On page 163, in the column for male adults in 1950 and beginning with Tioga County, the numerals for "hundreds" were dropped down two lines. Thus these figures should read: Tioga, 630; Tompkins, 442; Wayne, 167; Wyoming, 216; Yates, 362. There were no "unknown".

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